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Ponencias solicitadas formalmente

FOREST PRODUCTS RESEARCH AND THE MAINTENANCE OF THE TIMBER RESOURCE BASE

Developing Countries

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FDC: 8: 905.2: (213)--01

INTRODUCTION

Public opinion is increasingly concerned with the conservation of the world's forest heritage which also constitutes the timber resource base of the forest industries. At the same time, these industries are undergoing a profound metamorphosis.

For many centuries timber products were created in small cottage workshops and by family enterprises, and this is still the case in many areas. The last fifty years, however, have seen the establishment of large industrial production units, first in paper manufacture and later in sawmilling and panel production. The wood worker and wood technologist had to change their attitude from that of a craftsman to that of a production engineer. They now face the additional challenge of adjusting to computer-assisted design and manufacture.

This evolution is confronting researchers with the need for re-evaluating their goals : having been originally wood scientists concerned with the determination of the characteristics and applications of their material, they now find themselves obliged to serve the needs of an ever more competitive industry.

Research funding has also undergone a profound change over the last twenty years. From budget line appropriations it has moved more and more to financing of individual projects backed by government agencies or industries, with the introduction of a highly competitive element in the quest for funds.

These developments started in the industrialized countries in the 1960's : they are rapidly becoming a fact of life also in the developing countries. The principle that "the user pays" is being increasingly adopted and the number of laboratories financed entirely from government budgets is diminuishing.

What is the role of research in these new circumstances, and how can forest products research contribute to the maintenance of the timber resource ?

Although we do not agree with the artificial division of the world into "North" and "South", we shall in this paper adopt United Nations terminology and speak of "developing" (DC) and "industrialized" (IC) countries.

THE TIMBER RESOURCE BASE

The timber resource base are the world's forests which cover some 29.5 Mkm2* (1980). About half of these grow in the DCs most of which are located in the tropical zone (Table 1).

In 1986, this resource produced 3261 Mm3 of roundwood. In 2000 the production is estimated to reach 4100 Mm3. About half of this volume was used as fuelwood, the percentage being 78 % in the developing regions of South and Central America, Africa and Asia.

A dramatic increase in the consuption of industrial roundwood is foreseen in South and Central America, a smaller amount in Asia and very little in Africa. For fuelwood the expected increase is greatest in Africa. The percentage of fuelwood will still be 75 % in the DCs in the year 2000.

Use of wood for pulp will increase about 50 % in the USA, 30 % in Europe but 100 % in South America.

Trade flows from DCs to ICs are dominated by tropical woods of which Japan is the major importer with some 13 Mm3 (1987), followed by Europe with 6 Mm3. However, in absolute terms the major exporters are Europe, the URSS and North America. It is interesting to note that trade in wood and wood products occupies the fifth place in world trade with a total annual value of approx. 70 G$US, after oil and oil products, motor vehicles and machine tools but before wheat, minerals and other commodities.

When we look the sustainability of the production, we find that on a global scale, 15 % of the annual increment are harvested for fuel and another 14 % for industrial wood (Kauman 1986). The percentage is greatest in Europe and North America followed by the USSR, Asia and Africa (Table 2).

One might thus conclude that the resource is fully able to meet future demands but this is only true on a world average basis. In Europe, for instance, annual cutting is getting close to the annual increment and extensive new plantations will be needed to satisfy the expected increase in demand to the year 2000 and beyond. The recent phenomenon of dieback due to contamination and climatic factors, observed in Europe and North America, could upset current predictions.

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*In this paper, we use the following abbreviations: M million (e.g. M$), G Giga (a thousand million),

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TABLE 1

Forest Resources and Production in Developing Countries

Projection to 2000

Source FAO 1988

REGION	Closed Forests	Production							
		Fuelwood		Industrial Roundwood		Sawnwood and Sleepers		Wood for pulp	
	Mkm2	1986	2000	1986	2000	1986	2000	1986	2000
South America with Cen.America + Caribe	8.2	268	302	103	190	31	53	27	54
Africa (exc. Sth. Africa)	2.3	367	541	36	44	7	9	1	1
Asia (Tropical only)	5.3	212	246	100	138	32	46	7	9
Western Europe (for comparison)	1.4	42	40	235	303	73	84	113	148
U.S.A. (for comparison)	1.9	102	111	365	437	123	125	200	293
World	29.5	1680	2053	1581	2077	475	589	539	777

Notes : Fuelwood + Industrial Roundwood = Total Production
Sawlogs + PLy logs + Other = Industrial Roundwood
Sawnwood is quoted as sawn volume, all other items as roundwood equivalent
(Roundwood equivalent = 2 x sawn volume)

TABLE 2

Comparison of increments and Removal
Coniferous and broadleaved combined

Source : Brünig 1980
USDAFor.Serv.1980
FAO 1980

R E G I O N	GROWING STOCK IN CLOSED FOREST		ANNUAL REMOVALS 1980					
	Total	Annual Incre.	TOTAL Gm3		% of Growing Stock		% of Increment	
	Gm3	Gm3	Fuel	Ind.	Fuel	Ind.	Fuel	Ind.
World	304	10.0	1.54	1.38	0.5	0.5	15	14
Africa	43	2.0	0.34	0.05	0.8	0.1	17	2
North America	41	0.9	0.05	0.48	0.1	1.2	6	53
Latin America	82	3.2	0.21	0.07	0.3	0.1	7	2
Asia	34	2.3	0.79	0.21	2.3	0.6	34	9
Europe	15	0.4	0.04	0.29	0.3	2	10	72
Oceania	5	0.3	0.02	0.02	0.4	0.4	7	7
USSR	84	0.8	0.08	0.28	0.1	0.3	10	35

Adapted from Kauman 1986

In the DCs serious deforestation is making heavy inroads into the tropical forest. Although the destruction of forests is not as great as some alarmist media notices will have it, it is serious enough to cause grave concern. On a world basis, the annual destruction of tropical forests is estimated to be of the order of 70,000 km2, i.e. about 0.5 % of the total area of these forests.

In the Amazon basin of Brasil, cumulative deforestation since 1975 has reached 5.1 % of the Legal Amazon Region (Da Cunha 1989). If old historical deforestation in the States of Para and Maranhao is included, the figure would be 7 %, or about 8 % of the originally existing closed forest. The annual deforestation rate is 0.36 %, i.e. about 17,000 km2. These figures are much lower than predictions based on exponential models which were published in the press but serious enough to merit urgent attention.

Deforestation in the Amazon and indeed in most tropical forests is due to (Palmer 1988)

- Land speculation (i.e. legal validation of spurious land occupation)
- Agricultural settlement (legal or squatting)
- Cattle ranching
- Infrastructure (roads, hydroelectric dams)
- Mining
- Utilization of fuelwood and production of charcoal.

Timber getting for industrial purposes accounts at most for some 13 % of the total destruction of biomass (Kauman 1990).

Boycotts of tropical timber popular at present in some European countries are thus unlikely to make any significant impact on the destruction of tropical forests, apart from the ethical issue of whether the well-to-do countries of Europe have any right to interfere with the DC's utilization of their own natural resources.

The wholesale destruction of tropical forests can only be halted by determined political action. Initiatives such as the Brazilian "Our Nature" Programme are encouraging developments in this respect. The boycotts might have some limited, indirect value in stimulating protective legislation and other political measures in DCs without affecting timber production which is an important source of income in the poorer tropical countries.

PRESENT RESEARCH TRENDS

Some of the laboratories of the DCs are maintaining the traditional stance of concentrating on the advancement of basic knowledge and a few are selecting their research topics in accordance with the problems that receive attention in ICs. The majority, however, are moving increasingly towards research subjects of direct or potential interest to the forest industries of their own countries.

Thus, for instance, the Philippines are undertaking research on low-cost housing, waste utilization and the use of palm stems, Malaysia is looking for ways of deriving useful products from oil palm stems and at the manufacture of furniture from rubberwood, Brazil and the Andean Pact countries are examining the use of properly graded sawnwood for construction, and so on (Kauman 1990a). The examples could be multiplied. Many of the projects are funded by specially targeted national or international grants which aim to produce results that will be of immediate value to industrial wood conversion industries. This does not mean that basic research is entirely neglected but topics are chosen to underpin practical problems such as the biology of certain wood-destroying fungi or insects, the mechanical behaviour of wood from fast-grown plantations or the incorporation of new species into pulp production.

The most successful laboratories are those which have moved into technology transfer and in some cases have started their own enterprises. This applies particularly to some South American universities where the existence of a sawmill enables not only thorough practical training of students but provides also the possibility of carrying out meaningful research projects into cutting processes and production engineering. Such sawmills may produce timber on an industrial scale thus generating income which serves to improve the remuneration of researchers and to pay for some research projects.

Technology transfer is DCs is also often promoted by individual researchers who undertake consultancies in industry and sometimes by industry-sponsored and financed projects in institutes and universities or through foundations or companies associated with universities. The latter is a particularly recommendable approach as it enables the university to participate in the mainstream of forest industry development and to derive benefit for its students from the feedback of practical knowledge.

Participation in consulting and even manufacturing activities is also one way of circumventing the chronic problem of DC laboratories which is lack of funds and inability to pay salaries competitive enough with industry to attract top level research workers. Income from such activities may supplement university funding and provide additional incentives to researchers which are often the sine qua non requirement for them to continue working for a research institute.

Foreign grants and international "aid" including visits by foreign consultants, useful as they may be in specific circumstances, are of permanent value only if they contribute to creating a secure base for adequate funding and administrative independence of the institute after the assistance project ends.

In resume, then, present research trends in DC institutions are similar to those in most ICs. The importance of basic research is not negated but national development and the need to generate a more or less significant proportion of their funding direct their activities more and more towards industrial problems. This does not imply a reduction in the quality of the research since a research project connected with a production problem may represent an intellectual and scientific challenge as great as a fundamental project on wood properties.

A negative corollary of this trend is a reduction in the communication between researchers who are often working on confidential subjects. Great care and initiative is required that contacts are maintained on a personal basis and through seminars and conferences and that as much as possible of the results is eventually published in scientific and technical journals.

Much has been written about the utilization of the so-called "secondary" or "commercially less accepted" species as a subject for research by DC laboratories. This is going a little out of fashion since it is now recognized that the main problems connected with these species are adequate availability in the forest and sufficient similarity to a well-known species to serve readily as a substitute. What is needed today is a technico-economic approach associated with a well thought-out marketing research project (Sales 1989). Some important technological properties must, of course, be known but it is no longer considered necessary to spend a large amount of time in dressing a catalogue of all the properties of these species. Adequate grading and preservation methods, for instance, may be more important than knowledge of every single strength characteristic.

Lest it be forgotten let us stress again that only some 20 % of all wood harvested in the DCs is used for industrial purposes, the remainder being destined for firewood. Research on better production and utilization of firewood is thus of the utmost importance. The first of these aspects is being considered by one of the Projects of the IUFRO Special Programme for Developing Countries which deals with improving the productivity of multipurpose trees; we should also mention the Australian project on the introduction of secondary Australian species for firewood plantations (Boland and Turnbull 1989).

Better utilization of manufacturing residues may be part of the answer. The manufacture of sawdust briquettes, for instance, is at present considered uneconomical in some DCs. Research to improve the efficiency of the process may be appropriate. On the other hand, the improvement of stoves for cooking and heating is probably outside the province of the forest products researcher.

RESEARCH TO MAINTAIN THE TIMBER RESOURCE BASE

In the ICs research has an important contribution to make to maintaining the timber resource base by improving the yield and value of products obtained from trees. Every increase in recovery contributes to reducing the pressure on the forest and to reduce the unit cost of the raw material in the final product. Every increase in productivity improves the competitivity of the product and thus ensures an increased contribution of the forest resource to the national economy. Every improvement in quality assurance enhances the quality/cost ratio and thus customer acceptance of the product.

In the DCs the situation is different, and especially so in the tropics. The maintenance of the forest resource base is a matter of determined political action. Improvements in processing can at best have only a marginal effect on reducing the pressure on the forest. They do, of course, have a significant effect on the profitability of the timber industries.

There is, however, another aspect where research can have a much greater influence.

Notwithstanding the well-meaning and increasingly energetic efforts to maintain natural forests by gezetting reserves and national parks, in the long run the bulk of the forest will only survive if legislators and economic decision-makers are convinced that it constitutes a positive economic asset.

Wood is a very special material. In its common and cheaper forms derived from fast-growing plantations it excels for building purposes and other straightforward uses due to its anisotropic structure and easy workability, apart from its suitability for pulp, panels and other derived materials. In its more noble form of decorative wood obtained from trees grown slowly in natural conditions, it has a high aesthetic value and furthermore will appeal increasingly to the 21st Century person through being a "natural" and not a synthetic material.

Already today, people in ICs are prepared to pay high prices for so-called "natural" food although its intrinsic nutritive value is no greater than that of ordinary food. In the same way, we submit that in maybe 50 years' time, "natural" materials will be at a premium and many people will wish to live in homes with as little "synthetic" content as possible.

Beautiful woods derived from tropical, natural-grown trees will command premium prices for furniture, panelling, visible structural members such as laminated beams, provided that their performance is adequate and guaranteed for the purpose for which they are intended. This is where research comes in. A beautiful piece of furniture must have no surface checks, it must be dimensionally stable, have a clear surface without corrugations and blemishes which would impede a smooth satin finish. The wood from which it is made must lend itself to be bent and assembled into adventurous new forms which the inventive architect and furniture designer may conceive leaving full rein to his or her imagination. The list of desirable properties is endless.

Research on conversion, drying, chemical treatments which are environmentally friendly, preparation of perfect surfaces and many other aspects is needed to that wood may rise to its full potential and satisfy the consumer of the next century, while still keeping within affordable price ranges.

Whilst stressing the value of research on decorative timbers, we must not forget the need to vastly improve yield, quality and productivity in industries using wood derived from plantations and so-called secondary species which will continue to constitute the bulk of the income from the total forest resource.

If research fulfills its task, the future decision-makers will see economic advantage in establishing plantations large enough to supply all necessary timber for the common uses. There will be no question in maintaining a timber resource base of natural grown timbers of large proportions, in addition to national parks and reserves, if this consitutes a profitable use of the land compared to other opportunity costs. The recreation and production functions of the forest may well be combined to improve overall cost efficiency and there is no a priori reason why slow growing trees with beautiful noble wood should not be introduced into agro-forestry schemes.

The immediate task is to ensure the survival of a tropical timber resource base for the next twenty or thirty years. By then, let us hope research will have produced the results which will provide an obvious answer to the question of whether and how to maintain this base. Sustainable management is already possible on the basis of the knowledge existing today (Poore 1988) and once sustainable management produces a sustainable economic profit, it will seem absurd that there could ever have been a question of the disappearance of the tropical forest.

CONCLUSION

On a global scale, maintenance of the timber resource base is assured for the foreseeable future subject to unforeseeable developments such as a sudden increase in dieback. Vigorous plantation programmes should however be encouraged. In the developing tropical regions, maintenance of the timber resource base is a matter for determined political action to stop the destruction of the forest by land speculation, settlement, etc.

Research can help if it succeeds in assisting industry to create products which will satisfy the desire of 21st Century man and woman to live in "natural" surroundings such as homes built of and furnished with wood. This will transform the forest into an economic asset which will motivate decision makers to conserve it.

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FOREST PRODUCTS RESEARCH AND THE MAINTENANCE OF THE TIMBER RESOURCE BASE
- DEVELOPED COUNTRIES -

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FDC: 8--01

SUMMARY

Forest products research, i.e. mainly wood research, spans an extremely wide field of knowledge. Foresters, botanists, zoologists, chemists, physicists and wood technologists, process engineers, mechanical engineers, civil engineers, architects and economists all work towards the same goal, namely to secure the international recognition which wood deserves in the long run.

Many wood researchers are highly specialized. Hardly any of us have managed to maintain an overall view of the profusion of knowledge and the problems that remain to be tackled in the entire field. For this very reason IUFRO's Division 5 should discuss and attempt to establish a synoptic view. A closer cooperation between the heterogenous - and in their places of work frequently isolated - specialists must be reached. Why? Because step by step we have to approach our common goal of a future-oriented, successful forest management and forest products industry. Our motto could be: "Forests which, not least for ecological reasons, are becoming an increasingly pressing necessity, will only be conserved, tended and enlarged if society and in particular local populations can take recognizable economic advantage of forests i.e. in particular of their wood". Wood researchers all over the world actively contribute towards this objective to the best of their abilities.

Keywords: forests - wood and wood products - forest products research tasks

In the majority of developed countries the maintenance of the timber resource base is in the hands of forest management and silviculture. However, forest products research is making substantial contributions towards the maintenance and the improvement of the economic success of forestry and forest industry.

On a global basis wood is by far the most important forest product. Only regionally do other forest products such as resin, tannins etc. play a more important part than wood. They may, however, gain greater significance in the future.

Wood, as we all know, is a particularly versatile material with many positive peculiarities, some of which will call greater attention to themselves in the future. In this context the following points could be listed: - continuous growth under unique positive environmental conditions - available in great volumes - growing in many regions of the globe - high strength properties combined with low weight - decorativeness - relatively low energy consumption in wood products manufacture - decentralized wood-working industry.

Wood is, at the same time, a complicated material: - anisotropy of shrinkage and of strength properties - inhomogeneity - sensitive to insect and fungal attack - infinite number of wood species with great differences in properties - different properties within the same species related to growth region, site, stand treatment, growth rate, age of tree, harvesting time - differences between trees from the same stand - differences between the individual parts of each tree from base to crown - growth of wood dependent on adequate growth conditions: soil, air, water, temperature, hence adverse effects of immissions, global warming etc.

Considering the significance and the complicated nature of wood, wood research - even in developed countries - must be regarded as being fairly underdeveloped. This becomes particularly evident in a comparison of the amount of annually harvested wood with the annual production volume of other, partly competitive exhaustible materials (Table 1).

PRODUCTION OR HARVESTING VOLUME - WORLD 1987

Annual Production	Dry Weight (Mio t)
Forest Products	2011
Timber	980
Steel	740
Plastics	70
Aluminium	16

There is no doubt that the research capacity for other materials internationally backed by industrial concerns operating on a world-wide basis is disproportionately larger and more powerful than that for wood and other forest products.

Why is this so? There are many reasons for this unsatisfactory international situation in forest products research: Despite the strong increase in the size of plants, mainly in the field of wood-based panel manufacture and a few sawmills, large portions of the wood-working industry in Central Europe - and in other parts of the world - are still characterized by the smallness of production plants. These enterprises have little or no information on how to make use of the few existing research establishments and are thus seldom interested in making funds available for research and development projects.

Furthermore, the pronounced diversification of the forest products industry with its many branches and many regional associations and the existing conflicting interests often impedes rather than promotes the willingness to spend money on research.

These facts prove doubly disdavantageous for developments in wood utilization and forestry, as more and more countries will only provide public funds for applied research to the extent in which funding is initially provided by the corresponding industry. If e.g. the plastics industry puts up 1 Mio $ for some interesting research and development project this will, in some countries, elicit another 1 Mio from public research funds. When, where and how often are 1 Mio $ ever expected to come from the wood-working industry or one of its related branches for research and development? If at all, then only from big pulp and paper producing companies. This is the reason why in my opinion the situation of forest products research and wood utilization is not nearly as good as it should be - contrary to the optimism frequently expressed within IUFRO.

Considering the exhaustibility of other raw materials and hence the significance which forests and wood will acquire for the survival of mankind, the governments of all countries are called upon to do more for wood research in the way of public funds.

Which are the main gaps that have to be closed by increased research efforts? In the final essence every research team will have to decide this for itself. Still, in some fields it is obvious that more research and development is urgently required. The ideas presented in the following should be complemented, for example by discussions within IUFRO's Division 5.

Let's start with the tree: We are continually pointing out that we are producing a raw material whose properties can be influenced by forest management measures during the growth of trees. We are still a long way from knowing enough about "how" this should be done, e.g. about the consequences of our silvicultural methods, the prevention or reduction of growth stresses, reaction wood, spiral grain etc. The objectives for improving quality tree growth need to be better defined. With respect to the fear related to the adverse effects of immissions, global warming etc. and for general ecological reasons programs for an increased cultivation of mixed stands and thus of hardwood species are underway in many countries of the northern temperate zone. Therefore greater opportunities for mixed hardwood utilization, in particular for thinner diameters, need to be found. The wood properties of fast-growing species and the possibilities for influencing them, of course, also deserve special attention. Furthermore, in the interests of a homogenizing of timber grades investigations on better grading of roundwood have to be continued.

In pulp production alternative, non-pollutant processes which are being developed deserve equal acclaim as does continuous improvement of classical processes. A good start has been made to bring about the realization of the former. In this context there are also the possiblities of "bio-delignification", a stimulating development in the eyes of every biologist and chemist. Despite past successes in the field of the characterization and utilization of technical lignins or pulping liquors important tasks remain to be undertaken. Also, attempts at making use of the naturally growing macromolecule of cellulose for a great variety of products other than paper in competition with the exhaustible raw materials crude oil and natural gas seem most fascinating.

Globally, wood-based panels have secured an increasingly important place in wood utilization. Their variety and expansion is becoming greater, an example of this being the fast rise in production capacity of medium-density fiberboard, especially in North America and Europe. A greater number of board types will be created, but also compact cross-sections produced from chips and fibres which will compete with sawn beams. Problems in this field whose origins lay mainly in the glues used and in the retroactive formaldehyde release have been partly solved but need better solutions and increased research. Also, utilization of residues in conjunction with the further processing of panels and the expansion of the range of raw materials used in panel manufacture need attention and greater efforts by wood research scientists.

In the interests of an economically sound forestry anywhere in the world, i.e. for forest conservation, forest tending and expansion of forests worldwide, but also in the interests of the population of any country who covet healthy forests with a large percentage of major trees, the maintenance and expansion of solid wood utilization is of prime importance. Only a high portion of logs which can be sold at good prices for sawn wood or veneers will achieve this objective. Intense forest management practically lives off logs. In the field of solid wood utilization many advantages offered by the use of wood come into the limelight: Wood is a beautiful material for which mankind has developed a special affinity and from which a great variety of products are created under the lowest possible energy consumption conditions. All other consumers of the raw material wood should maintain an interest in solid wood being constantly uced as this is where a lot of cheap residues come from which are increasingly sought after by manufacturers of wood-based panels and also by producers of mechanical and chemical pulp. However, the field of solid wood utilization also poses large problems - in this context the inhomogeneity and anisotropy of grown wood becomes particularly evident. Therefore non-destructive testing and the prediction of properties of sawn wood is one of the most important tasks in research. Homogenization of inhomogenously grown wood by definitely improved grading should generally take first place in attempts to improve solid wood utilization. For the important field of structural timber in constructions a further improvement of jointing techniques plays an essential part, despite great progress achieved in the past. No doubt other fields of research such as improved drying, dimensional stability and resistance of wood continue to need our attention.

Unfortunately the ideal raw material wood - through some wood products - has been increasingly pushed into the role of environmental pollutant, if we consider keywords such as pulp and paper production and the bleaching of pulp, formaldehyde, wood dust, preservatives etc. A great deal of recent research energies have been spent on what could be called "defensive research" in order to prevent the natural raw material wood from losing its good reputation altogether. We must do everything to save wood from acquiring a bad name as a pollutant material. This also includes a better explanation of the actual causes of tropical forest destruction and the limited regional significance of wood harvesting which is involved. In the interests of healthy forests and the manifold uses of wood we must endeavour to develop better wood products with which wood will regain recognition as the raw material which can and should play a very important role in the future of mankind.

DEPTH AND DIRECTION IN DIVERSITY: PROGRESS AND FOCUS IN FOREST PRODUCTS RESEARCH

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SUMMARY

Forest products research reflected in the program of the Forest Products Division of IUFRO has increased both in depth and in diversity. The disciplinary orientation of Subject Groups has continued and strengthened. The interdisciplinary Project Groups have increased in number as new areas of interest and concern have been identified. These developments are important steps toward solving major problems of forest resource utilization, especially in view of continually increasing pressures on the resource itself. The goal of effective maintenance and use of the forest resource can be a valuable one for forest products research and can be attained by direction and focus in the many research groups of the Division.

I propose four points to guide in development and implementation of such direction:

1. Utilization of the timber resource is an essential element in its management.
2. Underutilized species and residues can substantially increase the timber supply without serious impact on other forest values.
3. The economic and marketing aspects of utilization need as much attention as the biological and physical.
4. We need simple solutions to real world utilization problems, but will often need sophisticated research to get them.

Keywords: Research management, research application, underutilized species

INTRODUCTION

We have heard about the warrior who, confronted with an obstacle, jumped on his horse and rode off in all directions. This provided lots of action, but it didn't accomplish very much.

I've been pleased during these past few years to see the developments in forest products research as reflected in the activity of Division 5 of IUFRO. These developments have added new directions and strengthened old ones, but they do not by themselves solve major problems in the use of timber resources . In this paper I will review a few highlights of where we have come and indicate some points about our relationship to the problem of maintaining the timber resource that are designed to give us some direction toward solving various elements of that problem.

WHERE HAVE WE COME?

We have continued and strengthened our programs in wood structure, anatomy, and quality, basic to much of what we do in the field. We have maintained strong programs to provide background for new developments in the use of timber as an engineering material, protection of wood for improved service in use, and processing to make more kinds of products from more kinds of wood more efficiently. These have been the work of our S Groups and their working parties. They provide disciplinary strength and depth that is essential to progress.

The most noticeable changes in program of the Division have come in our P Groups, those groups specifically organized to focus a variety of disciplines on areas of research that are of special interest in advancing the field of effective use of forest products. Advances in the biological and physical sciences and in many fields of engineering, together with a new awareness of needs and opportunities in forest products research in many parts of the world, indeed, even new concepts of what forest products research is, have added to the programs of our P groups and spawned new ones. For example:

P5.01 (Properties and Uses of Tropical Woods) has played a lead role in bringing researchers and research institutions in the developing world into contact with each other and with developed world counterparts to the mutual benefit of all.

P5.03 (Chemicals and Energy From Biomass) has developed renewed and invigorated interest in the efficient use of wood for energy. This is where most of the wood cut in the world is used and one reason for much of the reforestation and afforestation we see in most parts of the world.

P5.04 (Bamboo and Related Species) has not only been carrying on vigorous efforts on the bamboos, but extending this to rattans and palms and other sources of products that have too long been ignored in the formulation of research programs to meet human needs.

Since the last Congress in Ljubljana, we have added two new P groups and are on the verge of adding another.

P5.05 (Tree Ring Analysis) is bringing together the worldwide body of scientists concerned with dendrochronology and the relation of growth ring development to climatic and other growth conditions.

P5.06 (Forest Products Marketing) is focusing on the rapidly changing domestic and international market situation new developments in the basics and techniques of marketing -- now being recognized as a field that brings together knowledge of products with sampling and statistics and a fair degree of psychology and sociology.

A new group meeting here at Montreal for the first time is dealing with the long slighted field of non-wood forest products. In many parts of the world these are the products of most immediate interest and need to the peoples who live in and near the forest, both in terms of food and medicine and in terms of extracts, perfumes, medicines, and other items of trade.

We are rapidly becoming more diverse, but we must keep depth in our diversity. We are becoming more interdisciplinary, reflecting the fact that science and progress can often not be neatly pigeonholed, but we must be sure that we also have discipline. We cannot afford to squander these new opportunities by riding off in all directions.

WHERE ARE WE GOING?

The focus here today on "Forest Products Research and Maintenance of the Timber Resource Base" is an attempt to confront a major issue of the day. We hear most about it in the concern over destruction of the rain-forest, but it is equally applicable wherever pressure is mounting on the forest to supply timber together with the many other benefits, direct and indirect. Let's look at what this means in terms of research opportunities and challenges.

In guiding this look, I propose to make four points:

1. Utilization of the timber resource is an essential element in its management.

2. Underutilized species and residues can substantially increase the timber supply without serious impact on other forest values.

3. The economic and marketing aspects of utilization need as much attention as the biological and physical.

4. We need simple solutions to utilization and management problems, but will often need complex research to get them.

Point 1

Utilization of the timber resource is an essential element in its management.

Utilization provides the economic incentive for management of forest resources. This fact is especially significant when the forest resource is a key element in social and economic development or in maintenance of economic strength in a community or society. This is not only a matter of an unused, or inadequately used resource. It is a concern for the declining value of the resource with time during which it is not making its potential contribution.

Simula (1985) points out the close, dynamic relationship between economic development, economic strength, and the demand for forest products and services. He outlines the progression from traditional rural societies, such as are or were in most of the world through growth to post-industrial maturity and then to "ecologically oriented communication societies".

There are two broad options for using wood products from the natural forest in a manner designed to sustain the timber resource. One is to sustain the natural forest as such, using those species that grow naturally and intervening only to encourage species that are particularly useful. The other is to convert the forest to well-managed plantations which may yield 15 to 25 times as much wood as the natural forest. The first is usually looked upon as more environmentally desirable than the second. The second is usually more economically desirable and can be at least as effective as the first for such benefits as soil and water conservation, crop protection, nitrogen enrichment of the soil, and conversion of atmospheric carbon dioxide to oxygen.

In actual practice, neither option is ordinarily used exclusively, both are used to varying degrees. Both options require knowledge of wood properties, wood use, wood protection, wood conversion processes, and forest products markets for their most effective implementation. And in either option the products with which we are dealing may not necessarily be wood, but bamboo, rattan, or palm stems, or even such other non-wood forest products as food, fodder, medicinals, or others. The efforts of P5.01, as part of IUFRO's Special Program for Developing Countries have identified priority research needs for many of these in the developing world, as, for example, those outlined by DeFreitas et al (1986). Many developed world research institutions are also taking their cues from that, as well as from regular reviews of research progress and needs in their own countries. Too often, however, these programs are not closely related to the specific product use needs of effective forest resource management and maintenance. "Utilization" in this context then becomes the economical conversion, use, and protection of products of these differing types of forest to meet the needs of people, as reflected in the market.

Point 2

Underutilized species and residues can substantially increase the timber supply without serious impact on other forest values.

Preferences in use of wood species and quality levels have become well established in both the temperate and the tropical forest for centuries. In most parts of the temperate world, this has resulted in severe impact on the quality and area of the remaining forest for wood products production or even the essentially complete removal of the natural forest. In the United States, the area of commercial timberland has declined almost 8% during the past half century (USDA 1982). Stresses on the forest pose increasing risks (Smith 1990). Plantations of preferred species, often of genetically improved stock, are looked to increasingly to provide wood.

In the tropics the situation is generally much more complex, because of species diversity, increasing development and population and economic pressure, soil fragility, and the fact that we know much more now about the critical role of forests in maintaining the environment. It is estimated that 93% of the tropical forest volume world wide is made up of underutilized timber species (Freezaillah 1984). The fact that much of this volume is being burned or otherwise wasted after logging operations and conversion of land for agriculture, hydroelectric reservoirs, or plantations emphasizes the need for more effective use.

However, should underutilized species be used? Freezaillah (1984) cautions that the demand outlook is not bright as long as there are adequate supplies of preferred species and suggests increased attention to technical and market possibilities in areas that are not being logged intensively. Bethel (1984) emphasizes attention to the underutilized species primarily on a local, cottage industry basis with the objective of replacing them with productive species that can be managed efficiently. Youngs (1977) and Youngs et al (1978) suggest that mixtures of species can be used for pulp and for composite products and may expand options for silviculture, but this type of use may present environmental dangers if used intensively. Richardson (1977) raises the "Faustian dilemma" of intensive use as chips for such uses. In all of these, market considerations are likely to be at least as important as the more usual technical aspects and the first use is likely to be domestically in small-scale industry (Chudnoff and Youngs 1980).

On the other hand, industrial harvesting for wood in the moist evergreen forests of the tropics may take only 3-10% from only a few species and land clearing for agriculture may remove all of the timber and use very little or none (Salleh & Ho 1982). In many parts of the world, even those using relatively advanced technology, it is common to bring to the mill only half of the timber that is logged and to produce primary products from only half of that. Residues are being considered in a new light, however, in view of their possibilities for pulp, composite boards, or energy. Economy and technology dictate the degree and nature of use in these cases.

Point 3

The economic and marketing aspects of utilization need as much attention as the biological and physical

We talked about utilization providing the economic incentive for forest management. This is true, but only if products can be manufactured economically and marketed successfully. Improved technology pays off in improved economics. Improved economics pays off in improved marketing. Economic and marketing concerns begin at the local level, perhaps even at the family level in the avoidance of the need to buy the products they can pick up or manufacture from the forest. As the process expands, however, consideration expands to buying, harvesting, transporting, and selling the timber; technical and economic aspects of production; and the psychological, economic, and preferential views of the importer/merchant and the ultimate user (Kalafatis 1985). How much less can we afford to spend for raw material in the face of increasing production cost? Can we still make a product that will be useful and marketable?

In the increasing compartmentalization of research institutions, and of IUFRO itself, for that matter, due to the need for specialization, it is easy to lose sight or thought of these many factors of utilization. To a considerable degree, the "depth in diversity" I pointed to at the beginning of this requires so much concentration in a complex area that the rest is simply assumed or ignored. Yet integration of all factors is essential if any of our research is to have a lasting impact in the forest or in society. "Build a better mousetrap and the world will beat a path to your door"-- if it is also a more economical mousetrap.

Point 4

We need simple solutions to utilization and management problems, but will often need complex research to get them.

Study of the perpendicular-to-grain rheological behavior of wood and finite element analysis of strains across the grain during drying pay off in improved drying schedules.

Study of the rate of polymerization and compressive flow of polymers lead to improved adhesion between particles, flakes, veneers, or laminations, and pays off in improved composite products.

Expert systems are called upon to bring to bear a broad experience base on the study of the nature and arrangement of processing operations and pay off in improved products being made more economically. Computer-based digitizers enable the plotting of wood defects that are to be removed in such processing operations.

Reliability-based systems are used to determine design strength values for structural timbers.

Increasingly more powerful and efficient computer hardware and software are not only making possible the kinds of analysis that go with the research I have just mentioned but also make possible application of the results in design and manufacture of wood products. Powerful new forms of microscopy and spectroscopy make possible analyses of wood structure and behavior that we could only have dreamed of a few years ago.

With these amazing new tools at our disposal, it is easy to become caught up in the miracle and fascination of the tool itself, when the real payoff is in using these tools as tools to solve real world problems. Fortunately, some of the same advanced technology can be used to implement the solutions they make possible.

CONCLUSION

The increasing depth and scope of forest products research that is evident in the growth of the Forest Products Division of IUFRO provides new potential to make substantial improvements in both management and use of the timber resource. However, direction and focus on priority utilization problems of the real world will be necessary to realize the benefits of this strengthened research capability. The need to maintain the timber resource can provide this focus by keeping in mind that (1) utilization of the timber resource is an essential element in its management, (2) underutilized species and residues can substantially increase the timber supply without serious impact on other forest values, (3) the economic and marketing aspects of utilization need as much attention as the biological and physical, and (4) we need simple solutions to utilization problems, but will often need sophisticated research to get them.

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TOMORROW'S END USER NEEDS OF WOOD QUALITY FOR TIMBER CONSTRUCTION

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SUMMARY

Quality of wood is an expression of its characteristics: the degree of excellence it possesses in relation to its many and diverse uses. Wood quality is variable even within a tree species and is greatly influenced by natural or man-made forest conditions.

The needs of wood quality are strongly reflected by use requirements for houses and industrial construction. The challenge to provide in the future quality products for these important uses can be met through the application of biological, technical, and managerial knowledge.

Among the approaches needed, the practice of silvicultural principles and techniques is paramount. The practice must assure viable and high quality forest resource for generations to come.

Another approach must be the application and further development of technologies for the proper assessment of quality characteristics of structural wood products and their connections. Visual and mechanical grading or sorting of structural lumber requires improvement. For structural panel products, two basic philosophies co-exist for assigning property values, namely, commodity and performance standards. Better agreements on more uniform standards should aid broader market distribution.

Opportunities also exist for refinements of testing methods, quality control procedures, and manufacturing technologies with fasteners, adhesives, and preservatives. Such developments will benefit modern timber construction, especially with trusses, laminated beams and arches, I-beams and similar products.

Keywords: Wood quality, timber construction, quality assessment

TIMBER -- A UNIQUE, BUT VARIABLE RESOURCE

The availability of timber as a renewable, natural resource of many countries, its excellent working characteristics, high ratio of strength to weight, and good insulating properties have made it historically a desired structural material. In addition, many types of wood have characteristics, such as color, luster, texture, and figure, that have made them decorative materials of choice.

The quality of wood is an expression of its basic nature or characteristics, the degree of excellence which wood possesses in relation to its many and diverse uses.

Wood characteristics are to some extent species-specific. However, even within a species, the characteristics have often changed as virgin forest have been utilized and replaced with tree plantations or unmanaged reproduction. And in managed forests, the quality of wood has been and is greatly influenced by silvicultural treatments, tree age, and form (Daniel et al. 1979). The variety of timber resources in many species, sizes, and shapes often challenges people in their proper selection and utilization to meet a multitude of demands.

To use wood most effectively in engineering applications, the effects of specific characteristics of different tree species, grades, and sizes must be considered. Processing steps from the forest to the final end-use have also a pronounced influence on the structural performance of products. Unfortunately, their influence on product quality is often considered secondary, because efficiency in processing and quantity yield are paramount, especially in primary manufacturing. Originally, in most timber growing regions of the world, the wood supply was abundant and inexpensive. This changed with the growth of populations and industrialization, leading to increasing land and timber prices. Today, market and price constraints are of major concern to the forest industries.

The purpose of this paper is then to provide a broad overview of wood quality issues influencing timber construction in the future. The contents reflect the impressions of the author received through professional contacts during the last years, however, the time frame available for writing did not allow for a global literature search required for a state-of-the-art technical review.

Major Uses

The major uses for wood are in housing, industrial construction, and furnishings. In the hierarchy of human needs, sheltering is near the top. Decent, safe, and affordable housing is of utmost importance to the stability of families and communities. Housing means more than shelter with some amenities to people who occupy it, because almost always, a home is an elemental reflection of personal identity and dignity. Nothing reflects that personal identity more than the furnishings in a home. In fact, the use of wood in designing, building and often carving of furniture and ornaments has reflected the cultures of people more than anything else, excepting graphic art.

However, after many years of only partially successful efforts to adequately house ever increasing populations, the goal to provide affordable housing is still elusive in industrial and developing nations alike. Wood and products derived from it can greatly aid in meeting people's needs.

Industrial timber construction experienced a renaissance during the last quarter century because of the availability of technologically advanced structural components and systems, such as structural glue-laminated timbers and metal or wood plate connected trusses and I-beams (American Institute of Timber Construction 1985). Glue-lam beams and arches are meeting standards of heavy timber construction with the durability necessary under exposure to fire. Together with Gothic and constant radius arches, these products have allowed designers to build large and beautiful structures for commercial buildings, sports arenas, churches and other assembly halls. Trusses, on the other hand, made possible the development of efficient, but low cost, shelters for commerce, agriculture, and industry. Advanced engineering designs, combined with highly quality controlled manufacturing procedures, have made wood highly competitive in the industrial construction market.

Major Products

Historically, poles and beams were the first structural wood products used by man to escape their confining caves. Lumber was the first primary industrial product to satisfy the three market sectors of housing, industry, and furnishings. But with increasingly better technology, new products were developed, such as plywood, laminated beams, trusses, fiber and hard boards, structural flake board, oriented strand board, laminated lumber, and similar composites.

The major functions of these products are structural, either load-bearing or enveloping, and esthetic. The proper use of wood is extremely important to provide the desired service for long time periods. Especially in industrial societies with diversified markets, manufacturers of wood products need to deliver satisfactory materials as they face possible substitution of their products by other materials. Wood products compete in one of the freest markets with other materials, especially with metals, cement, and brick for buildings, as well as plastics and textiles for furnishings.

GENERAL NEEDS

How can we plan wisely and develop our future supply of quality wood materials?

Foremost is the need for communication between foresters and wood technologists on the one hand and between manufacturers of wood products and builders, architects, and engineers on the other. Foresters have for long aimed at producing the largest volume of timber per unit time and area, often with little attention to the quality of the material being produced. However, many have indicated an ability and willingness to grow timber in such a way that it would best meet the requirements indicated by wood technologists. They, in turn, have accepted whatever raw material was being provided and attempted to make better products from materials that declined in quality over time.

Needed for commercial forests is an assessment of stand management practices on the basis of biological and technical knowledge. The desired information pertains to the impact of

(a) silviculture on both volume and value of logs determined from a final product perspective;
(b) technology in terms of desired properties and quality of products; and
(c) economics for the optimization of investments.

Such information is best obtained by multi-disciplinary teams who review and suggest management practices, predict wood quality and, from these, derive economic and market consequences of silvicultural and technological options.

To best meet the requirements on present and future construction materials, it is necessary to

(1) maintain and possibly improve the forest resource;
(2) select for wood quality in the forest and through all manufacturing steps;
(3) maintain the material's quality through correct identification of conversion processes and prevention of deterioration during manufacturing steps such as storing, drying, treating, transporting, etc.; and
(4) properly assign finished products to meet the design requirements or obtain desired performance.

To limit the scope of this paper somewhat and not to overlap too much with other speakers' topics, the following comments pertain mainly to topics 1 and 4.

Quality Timber from the Forests

In the future, excepting the remaining virgin forest areas, so called "man-made" forests will supply most timber. In the next century, most trees will be harvested from plantations. In a number of tropical developing countries, native, but commercial forests will see a slow, but deliberate shift from a practice of utilizing very few high quality species to an era of multispecies utilization. This is expanding into future harvest of secondary regrowth of tropical timbers (FAO 1982, 1985). In addition to plantation species, species from agro-forestry systems will add to the availability of timber.

Whether in tropical, subtropical, or temperate climates, experience teaches to expect lower quality wood. The causes of degrade in lumber derived from young-growth trees are knot size and frequency, juvenile and reaction wood, as well as wide annual rings. Fast grown plantation trees contain a high proportion of juvenile wood which is, especially in conifers, in many ways inferior to mature wood (Resch and Bastendorff 1978). In comparison, juvenile softwood has lower specific gravity, shorter fibers, thinner cell walls, less alpha-cellulose, but more lignin, in general all contributing to lower strength. The cell walls of juvenile softwood contain micro-fibrils arranged with a flatter angle causing greater longitudinal shrinkage when the wood dries and, therefore, warping of the product (Thomas 1984).

Forest managers have the opportunity to influence tree growth and with it wood quality through both silvicultural treatments (Clark and Saucier 1989; USDA Forest Service 1988) and, to some extent, the use of genetics. But they have to make some choices among silvicultural methods:

(1) Close planting and little to moderate thinning will slow the growth of individual trees with smaller branches in the long run, causing natural pruning with some species. This method also leads to smaller cores of juvenile wood within tree boles. After cessation of juvenile wood growth, the development of higher quality mature wood can be accelerated through thinning and fertilization and sometimes even irrigation. Accelerating the growth rate generally tends to decrease specific gravity and tracheid length in trees. Because juvenile wood is deposited only during the first ten to twenty years in the life of a tree, longer rotations yield in general higher quality timber.

(2) Another, almost contrary, approach uses wide spacing for seedlings when establishing plantations. The growing trees first form large cones of juvenile wood around which they later deposit a greater volume of mature wood. Unfortunately, they also form larger branches, that is, larger knots in lumber. The ratio of life crown to tree size determines where auxins and carbohydrates are being produced. These materials have strong influence on the extent of juvenile wood, the proportion of early-wood to late-wood, and the position in the stem of maximum ring width and hence stem taper. The life crown ratio can be controlled directly by pruning which greatly improves wood quality and resulting lumber grades. However, this practice is deemed too costly in many countries.

Genetic improvements hold great promise in the long run. Important wood properties such as specific gravity, fiber length, and fibril angle are genetically controlled. So are desirable tree characteristics such as tree form inclusive of the important straightness and branchiness, on the one hand and resistance to pests on the other. Tree breeding has already been practiced successfully, especially with pines during the last decades. Biotechnology in forestry is only in its infancy, but promises, when successful, quicker and more complete success.

Quality Products for Construction

To use any material structurally, it must be presented in terms acceptable to the builders, architects, and engineers of a particular country (Hoyle, Jr. 1972). The design and construction of many structures, made entirely or partially of wood, can be carried out without the direct design by engineers and architects. However, builders of non-engineered structures need the full understanding on the part of building regulatory officials, who develop building codes and recommend building practices. Building authorities will permit and encourage the use of wood and wood products only when good reliable knowledge of engineering properties has been developed. In addition to technical descriptions of wood based building materials, design practices for wood systems peculiar to different countries or regions must be justified and explained. Particular building practices, traditional for different countries, often require special explanations.

There is a substantial need to produce and present information in a form acceptable to professional builders, architects, and engineers in private industry and government agencies, without which broad and general acceptance of wood even in less sophisticated buildings may be jeopardized (USDA Forest Products Laboratory 1980). Fortunately, a great amount of information obtained through research in many countries is available for use. The world literature is filled with such information on building and timber technology. Countries that have not yet developed an information base on wood can take advantage of such information with relatively little research and will be able to adapt these resources to their own special needs. Obviously, methods of structural analysis need to be demonstrated in the context of local timber for the builders and engineers of a region. If the technological competence does not fully exist, the missing elements can be developed through education and technology transfer within universities and trade schools, as well as continuing education events for professionals.

An important link is needed between the manufacturers and users of forest products. Industry associations must exist to establish and maintain standards for sizes and quality of products. These standards provide a basis for recognized values and are for the use by inspection services that maintain the integrity and uniformity of the standardized products. In this way, the interests of manufacturers, distributors, and consumers become equally protected. In most countries, these important standardization and inspection functions are carried out by trade associations and/or public offices under government supervision.

Lumber

Worldwide experience shows that wood has very similar fundamental characteristics of viscoelastic and time-dependence behavior (Galligan and Green 1984). To assign properties to structural lumber, two basic concepts have been employed:

(1) The visual system of grading requires the correct and proper identification of species and visual characteristics such as knots, slope of grain, juvenile wood, compression failures, decay, and various manufacturing defects, such as splits, checks, and warp. The traditional, piece-by-piece grading process attempts to predict adequate performance for three general categories of structural lumber: general purpose or "yard" lumber, elements for trusses and I-beams, and laminating lumber. The design stresses are based on the relationship of such characteristics or defects to clear wood as usually outlined by standard setting agencies.

Because the efficiency of the visual grading system is pretty much determined in the marketplace without strict quantification in the engineering sense, the so-called In-Grade Testing Program has been undertaken in North America during the last decade (Madsen 1978). It is a major, but costly, step away from a system that is based on the determination of properties on small, clear, straight grained wood samples obtained from a number of trees within a species. The In-Grade Lumber Testing Program determines grade-size-property relationships for the most important grades and sizes of full size lumber through the testing of bending, tensile, and compressive strength as well as stiffness (E) in bending . This knowledge is considered necessary in anticipation of new reliability-based design procedures for wood. Reliability of structural performance with wood should be the same as for structures built with other materials for the same purpose. The reliability of performance of given structures depends upon the probability of occurrence of the design load which is independent of the material used. In the United States, the reliability of lumber design properties is thought to be ninety-nine percent or more.

(2) The machine grading system or machine stress rating (MSR) is the other major grading process. This system measures the stiffness of each piece and depends to some extent on species identification. The relationship between stiffness and strength, together with an edge-knot override, is used to assign a stress value to each piece. Unfortunately, not easily discerned defects such as compression failures and incipient decay, as well as inadequate drying, detract from the prediction efficiency of the system, leaving about forty to sixty percent of the strength variability unidentified. MSR became industrially used in the 1960s and is now employed in many countries for determining the largest proportion of the higher grades of structural material, including elements for trusses and I-beams.

The production of laminated lumber uses the E-rating process for the evaluation of stiffness. Each piece is graded on that basis, together with criteria for knot size and location and, more recently, for its own size. This size effect reduces the assigned stiffness values of the larger pieces. Such grading assures placement of rated boards in the appropriate locations in laminated beams.

While MSR focused first exclusively on bending strength, the importance of tension strength testing has become widely recognized because of deficiencies discovered in previous assumptions, specifically the disproportionate influence of the foremost mentioned edge-knots on tension strength. The recognition of the size effect, now long accepted for bending strength, also applies to tension. This appears as a consequence of the impact of the Weibull theory of size influence.

Panels

Structural wood panels have changed the approach to residential and commercial construction during the last four decades. Starting with much broader commercialization of structural plywood in the 1950s, research and industrial development led to the continuously increasing use of composites, which replaced lumber as the dominant sheathing material for the construction of floors, walls, and roofs. To a lesser extent, structural panels are sold for materials handling and transportation, general maintenance and repairs of residential, farm, and industrial buildings.

A dominant role is being played by plywood which is assembled from veneers laid up in alternate layers and bonded usually with phenolic resin. Oriented strand board, in contrast, is composed of three to five layers of strands with each layer oriented perpendicular to the next and bonded as well with phenolic resin. Wafer board is similar, however, composed of rather large, square wafers in three random layers with the largest flakes laid on the faces of panels to assure high mechanical properties. Particle board, in contrast to structural products, have usually small particles and can be bonded with synthetic resins as well as Portland cement. Finally, COMPLY® combines face veneers and a structural core of strands or flakes or particles.

Regardless of the make-up of these panels, standards for construction and industrial use have been promulgated by standard-writing official bodies. Such commodity standards are basically manufacturing prescriptions to assure the market that minimum properties required for general construction have been met. Many well documented quality control tests carried out in the manufacturing plants are used worldwide.

During the last decade, manufacturing associations have asked for new performance standards for their products. These standards first define the end-use of the product and derives from it requirements to satisfy a particular application in construction. Thus, performance criteria and test methods must be defined. The products are span rated for application in floors, walls, and roofs when braced with horizontal or vertical framing elements.

The testing of the performance of panels includes static and dynamic concentrated loading, uniform wind or snow loads, holding ability of mechanical fasteners, and shear resistance for wall bracing. In addition, evaluation of physical properties such as panel expansion and bond durability must be carried out. These are laboratory tests simulating exposure to the weather.

Organizations certifying the performance of panels must guarantee values for the above mentioned requirements and monitor bending strength and stiffness, thickness, density, and other information related to manufacturing and service of the product. Building officials of code agencies must accept the performance standard and approve the quality control procedures, including a panel sampling plan, and the "grade" stamping of the product. The mechanical properties need to be tested on full-size panels to assure strength and stiffness in bending, tension, compression, shear, and the modulus of rigidity.

As mentioned above for lumber, reliability based design methods will also affect the application of structural panel products. Based on considerations of the statistical nature of structural loads and the serviceability and strength limit states, the reliability of structural systems can be determined. Because of the statistical nature of the product properties a database needs to be established to develop a full understanding of the capabilities of the materials to resist different loading conditions and code requirements.

Major Components

The construction of buildings requires the connection of lumber, timbers, and panels and, therefore, allowable design values for a whole variety of connection systems. Mainly because of the tremendous number of mechanical fastening devices, design practices are empirical with few verification tests. Now, because of the availability of computers for the analysis of structural systems, the need for better information on strength and stiffness of joints has allowed engineers and designers to increase the safety of structures and/or make construction more economical. In the light of recent earthquake and hurricane disasters, an added impetus has been given to obtain test results not only on statically, but on dynamically loaded assemblies. They have to provide adequate resistance to forces transmitted across joints to meet ultimate limit states. Joint rigidity and/or stiffness must meet serviceability and ultimate strength requirements. Finally, the way in which connectors reduce the strength of the jointed members needs to be considered.

Bolts, nails, and screws transmit forces of withdrawal, axial loading, and/or shear. Metal plate and "glue-lam" rivet connectors are mainly used to transmit shear; however, they are limited by their resistance to withdrawal. Shear plates and tooth or split rings transmit shear forces only.

The large body of literature dealing with fasteners makes it difficult to focus on the most important quality related questions. However, specific problems point the way to future testing and quality control needs. One particular concern is the behavior of mechanical fasteners in light frame structures when exposed to fire. Corrosion of fasteners, especially when made of metal, and/or the degradation of wood that has been treated with preservatives, needs to be better understood, especially for environments with high temperature and humidity. Alternatively, non-corrosive connectors made of fiber glass or other plastic composites should be developed further and substituted where opportune. Load duration effects on joints need to be understood when the strength of a system must be known for engineering design.

Adhesives provide a special form of connection. The forest products industries have relied heavily on phenol formaldehyde and resorcinol for exterior use. Melamine, isocyanates, and epoxies have been introduced to a much smaller extent. Quality control procedures for testing of adhesive joints are well documented and known.

Because of the dependency on petroleum derived adhesives, the desire exists for their partial replacement with components obtained from renewable resources. However, insufficient research has been carried out on the performance of carbohydrate-modified phenol formaldehyde adhesives or polymers, such as furfural polymeric systems, that could totally replace petroleum-derived adhesives. Of course, the search for phenolic materials derived from wood and bark to partially replace oil derivatives has continued for quite some time.

To assure the adhesive bonding of preservative treated or basically refractory wood surfaces, a great deal of research will be needed to obtain a fundamental understanding and advance it to commercial practice.

Trusses, I-beams, and similar manufactured structural components have found widespread use for the construction of roofs and floors (American Institute of Timber Construction 1985). These structural members make frameworks for light, strong, and rigid structures. Trusses, especially, can be composed of relatively small pieces of lumber and, because of the triangulated system which resists both tension and compression forces, are capable of relatively long, clear spans. They exhibit high resistance to dynamic loading situations such as earthquakes and heavy winds. Mathematical capabilities and the use of computers have led to excellent analytical methods and models, so that a need for better design methodology does not seem to exist.

Quality control problems are best defined in response to actual problems. Such have been experienced with inadequately manufactured finger-jointed lumber or the damage of finger-joints by truss plate teeth. Other potential problems relate to the corrosion of metal plates or their behavior in fire.

In-place dimensional changes of lumber have caused the "rising truss" problem. Damage is caused by excessive longitudinal shrinkage of juvenile wood and/or compression wood. Seasonal climatic changes resulted in arching of trusses and consequently in the separation between ceilings and walls. This condition commonly occurs when the lower chords of trusses become dryer and shrink more longitudinally than the upper chords. Obviously, the elimination of juvenile and reaction woods becomes an important quality control step.

Fabrication of I-beams made of various combinations of wood products has increased appreciably during the last decade. Flanges are usually made of solid or laminated-veneer-lumber, while webs are composed of plywood, structural composition boards, or hard board. A real need exists to obtain more complete data on the performance of such I-beams under long-term loading and moisture content cycling.

Glued-laminated beams and arches are an example, par excellence, for wood products which efficiently utilize wood in its variable form and distribute its defects, thereby reducing strength variation. In addition, glue-lams can be designed in a most efficient way by using laminates having different moduli of elasticity in different laminating zones, so as to either increase the loading capacity of the product or the economy of its manufacture, or both. A number of manufacturers follow a moving target, however, because the available raw material changes continuously. They face not only variations within a species, because of insufficient supplies, but often see the need to introduce previously unused wood types.

Better utilization of machine stress rating and tension proof loading should overcome existing and potential future problems. For this purpose, small manufacturing operations require simple, but reliable MSR or E-rating machines. Another approach is the use of specially manufactured tension laminations, such as laminated-veneer-lumber, which have much more uniform strength properties. New computer-based models for the mathematical examination of engineering properties of new grades of laminates and their combination into full-sized beams will need to go hand-in-hand. In the recent past, an increase in the use of hardwoods into glue-lams has taken place. With the introduction of lower density species, the shear strength of laminated beams manufactured from them could become a limiting factor and needs to be carefully investigated by designers.

Interest in timber bridges and their design is increasing. They appear to have real advantages when connecting second and third degree roads, especially in rural areas. Except in areas with virgin forests, glue-laminated beams have now replaced large, solid timbers. A key element in this development is the effectiveness of preservative treatments with a number of timber species. For somewhat refractory wood, the use of parallel laminated-veneer lumber provides a technological solution. Preservative penetration and improved retention is possible because of the development of lathe checks during the peeling of the veneer. This new product may also have a lower variability in strength than the solid lumber normally used for laminations. On the other hand, the manufacture of laminated-veneer lumber requires more quality control, especially in the lay-up and gluing operations.

Preservatives

Preservative treatments assure the safe and long service not only of laminated timbers but also of all other forest products exposed to the weather or in contact with the soil. Creosote and pentachlorophenol treatments have provided excellent protection to poles and railroad ties for many decades. Water-borne salt treatments are preferred wherever persons may come in contact with the treated materials, even though the treatments could cause additional checking and dimensional changes. Because of questions related to human health and safety, as well as environmental impacts, new preservative formulations are being and need to be developed, together with appropriate treating methods. During the last years, compounds such as copper-napthenate and quaternary ammonia combinations have received rekindled interest because of their relatively safe environmental impact. The need for such compounds for joinery timber apparently sparks healthy competition among manufacturing companies.

More forest products will need treatment with fire retardants to meet ever stringent building codes (Kordina and Meyer-Ottens 1983). It is anticipated that preservatives will be developed for the protection of building components against both fire and insects, particularly with borate formulations. Concerns have been expressed that some fire retardants such as ammonium-phosphates may cause chemical deterioration of wood at high temperatures and humidities. Long-term durability tests are already planned to study these formulations.

Where a single treatment will not suffice, as in the case of pilings in the ocean and brackish waters, dual preservative treatment becomes mandatory. In all these cases, the influence of treatment on the engineering properties and performance of individual construction members must be researched and reflected in design specifications.

CONCLUSION

Assurance of the quality of wood products to be used in building houses and in industrial construction is of utmost importance. The raw material supply for future activities must be guaranteed by forest managers through employing up-to-date silvicultural methods. Manufacturers of forest products will need to protect the intrinsic values of wood throughout the conversion process and enhance them through proper technologies.

Manufacturing associations and public agencies share in the responsibility to develop and implement procedures for product quality assurance. They assign appropriate grades and values to characterize the expected performance of products, so that designers and builders are able to make the correct materials selections. The development of recommended design values reflects a balance between safety and economy.

Recommended design values, building codes, and standards vary by region and by country. International efforts to come to agreement on basic values of timber quality, vis-à-vis general structural requirements, appear to be very important. Better agreements should enhance wider use and trade of timber products. However, as this paper indicated, technical improvements and new developments of products and testing methodologies make agreements on these matters moving targets. IUFRO, through its various working groups, can make significant contributions by not only developing a body of pertinent knowledge, but also sharing it with industry leaders and regulatory agencies.

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TOMORROW'S SUPPLY OF GENETICALLY IMPROVED TIMBER

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SUMMARY

Planting programs are expanding worldwide with the current level at 14.5 million hectare per year. Much of this is of genetically improved material. Some wood of older plantings of genetically improved trees is being harvested now, but it will not become available in quantity until shortly after the turn of the century. Because of the high productivity and accessibility of plantations a substantial portion of the wood consumed will be derived from plantation-grown genetically improved trees one or two decades later.

Keywords: Breeding, tree improvement, plantations, wood quality.

INTRODUCTION

Good worldwide statistics on this topic are simply not available and even general statistics on forested area, area in plantations and amount of annual planting are rather fragmentary and highly variable in reliability. However, based on the general statistics available and some familiarity with worldwide activity in the field of forest tree improvement it is possible to put together a reasonable picture of the supply of wood from genetically improved trees during the next two decades and the kind of wood to expect from these trees.

BACKGROUND INFORMATION

Worldwide, there is about 4 billion hectares of land classified as forests. The FAO classifies forest lands as closed-canopy stands, open-canopy stands and shrub and fallow area. Of these, only the closed-canopy stands, of which 2.6 to 2.8 billion hectare exist, can qualify as suitable for commercial production (Table 1). Of these, over 90 million hectares are

Table 1: World Forest Resources (Brown 1984)

Region	Closed Forest	Open Woodland	Forest Fallow and Shrubland	Total
	(Million hectares)			
Tropical America	679	217	316	1212
Tropical Africa	217	486	609	1312
Tropical Asia	305	31	109	445
North America	470	176	-	646
Europe	140	29	1	170
USSR	785	115	15	915
Pacific Area	80	105	5	190
Total	**2676**	**1159**	**1055**	**4890**

Table 2: Estimated areas of established plantations in the tropics at the end of 1980 (Lanly 1982)

Region	Industrial			Non-Industrial			Total		
	Hard-wood	Soft-wood	All Species	Hard-wood	Soft-wood	All Species	Hard-wood	Soft-wood	All Species
	(Thousand hectares)								
Tropical America	997	1571	2568	2002	50	2052	2999	1621	4620
Tropical Africa	456	541	997	777	6	783	1233	547	1780
Tropical Asia	2896	606	3502	1383	226	1609	4279	832	5111
Total	**4349**	**2718**	**7067**	**4162**	**282**	**4444**	**8511**	**3000**	**11511**

in industrial plantations. This is about three percent of the closed-canopy forests. Judging from statistics available for the tropics adding non-industrial plantations could add a good 60 percent to this area (Tables 2 and 3). The forested area in the developed countries is relatively stable and slightly increasing, while the forested area in the developing world, particularly the tropics is rapidly declining. Deforestation of tropical forests is taking place at a rate of about 7.5 million hectares per year for the closed-canopy forests, about 11 million hectares per year for all forest areas combined (Table 4).

Table 3: Worldwide estimate of industrial forest plantations as of 1985 (Postel and Heise 1988)

Country/Region	Area
	(Thousand hectares)
Soviet Union	21,900
China	17,500
United States[1]	12,107
Japan	9,584
Brazil	3,500
India	1,960
Indonesia	1,800
Canada[2]	1,528
Chile	1,227
South Africa	1,115
New Zealand	1,089
Australia	838
Argentina	550
South Korea	400
Nigeria	270
Western Europe[3]	13,000
Other	3,335
Total	**91,703**

[1] Includes only industrial plantations in 12 southern states and in the Pacific Northwest, accounting for at least 90 percent of planting for timber.

[2] Includes only plantations established since 1975.

[3] Plantations as of 1975.

While the forested area is diminishing, wood consumption has been steadily increasing and is expected to continue to do so. Wood use increased from about 730 million cubic meters in 1960 to about 1233 in 1980. It is forecast to surpass 1800 million cubic meters by the year 2000 (see Table 5). Even though plantations constitute only about three to five percent of the total forested area, they will contribute much more to the overall wood supply, because of their greater productivity and accessibility. (see Table 6).

DEVELOPMENT OF PLANTING PROGRAMS

Although people have planted trees for thousands of years, the scale of planting programs has increased spectacularly during this century. There was a large peak in planting in the United States during the great depression in an effort to put people back to work, but tree planting really has been accelerating since World War II (see Table 7). While in the southern United States planting has mostly been done with native trees, in other areas large-scale planting has been often associated with the introduction of exotics. This is particularly true in the tropics where pines are introduced on a large scale because of their desirable wood properties and eucalypts because of their spectacular growth.

Planting in the tropics currently is over one million hectare per year (Table 4) and is expected to increase to compensate for the losses of forest area and in response to the threat of global warming. As can be seen from Table 8 almost half of the planting in the tropics is southern pines. Smaller amounts of other pines are being planted. Of the hardwoods a substantial portion consists of eucalypts.

Worldwide , about 14.5 million hectares are being reforested (Table 9), most of it in the temperate zones of North America, Asia and Europe.

Table 4: Deforestation and afforestation in the tropics for the period 1981-1985 (Lanly 1982)

Region	Closed canopy forests	Open grown forests	All	Thousands of ha planted
		(Thousand hectares)		
Tropical America (23 countries)	4339	1272	5611	535
Tropical Africa (37 countries)	1331	2345	3676	126
Tropical Asia (16 countries)	1826	190	2016	438
Total (76 countries)	**7496**	**3807**	**11303**	**1099**

Table 5: Total demand for forest products 1960-2000 (FAO 1982)

Year	Total demand
	(Millions of m^3)
1960	732.8
1970	1032.6
1980	1233.0
1990	1493.4
2000	1818.5

DEVELOPMENT OF TREE IMPROVEMENT PROGRAMS

Although published work on the genetics of forest trees dates back as far as 1760 (Larsen 1956), most current tree improvement programs were initiated after World War II. C. Syrach Larsen from Denmark, Ari Gustafson from Sweden, Keith Dorman and Bruce Zobel in the United States and Hyan in Korea were among the pioneers in this field. The Swedish program served as a model for many of the others. By 1963 when the first world consultation on forest genetics was held in Stockholm, active programs were underway all over the world including Argentina, Australia, Austria, Belgium, Brazil, Canada, Czechoslovakia, Denmark, Finland, France, Germany, Great Britain, India, Italy, Japan, Korea, Morocco, New Zealand, Norway, Poland, South Africa, Southern Rhodesia, Spain, Sweden, Tunisia, USA and Yugoslavia,

The timespan over which these programs developed was rather short, but in general they were initiated at high latitudes and spread from there to warmer climates. Many of these programs have been active and productive over several decades. This sequence of development has some important consequences for the availability of wood from genetically improved trees.

Table 6: Forecasts of average annual production of wood for industry in the tropics in millions of m^3 (Lanly 1982)

Region	1983 - 1987 (average)					
	Hardwoods			Softwoods		
	National forests	Plantations	Total	National forests	Plantations	Total
Tropical America (23 countries)	27.6	18.8	46.4	12.1	22.2	34.3
Tropical Africa (37 countries)	16.7	2.6	19.3	0.2	4.6	4.8
Tropical Asia (16 countries)	102.0	4.6	106.6	3.4	0.1	3.5
Total (76 countries)	**146.3**	**26.0**	**172.3**	**15.7**	**26.9**	**42.6**
Number of ha (thousands) productive forests	827941	5919	833860	20107	4049	9968
Productivity (m^3/ha yr)	.17	4.4	.21	.78	6.6	4.3

AVAILABILITY OF WOOD FROM GENETICALLY IMPROVED TREES

The initiation of a tree improvement program is not necessarily followed shortly by the production of genetically improved seed. There are several reasons for this. Some programs were purely research programs, such as the Institutes of Forest Genetics of the U. S. Forest Service. Other programs focused on hybridization without having the means of mass-producing hybrids. Most of all there is an enormous time lapse between the initiation of a tree breeding program and the time that significant quantities of wood resulting from that program are harvested. In the southern United States the time lapse is approximately 50 years. In Canada and Sweden the time lapse may be 75 - 100 years, while in the tropics the delay could be as little as 10 - 20 years. Since tree improvement has spread, more or less, from Sweden and Denmark southward it is very likely that wood from genetically improved trees will become of available simultaneously in many places of the world. In the southern United States planting of genetically improved material started in the 1970's and currently most of the material planted is genetically improved (Table 10).

Table 7: Tree planting and direct seeding in the southern United States from 1925 - 1987 (Lantz 1988)

Year	Public Land	Industrial Land	Non-Ind. Private	Total
		(Thousand hectares)		
1925	1	7	6	13
1930	1	3	2	5
1935	81	1	9	19
1940	24	3	45	72
1945	1	3	19	23
1950	18	53	48	119
1955	14	97	92	203
1960	28	201	411	640
1965	37	164	93	295
1970	38	245	72	355
1975	47	366	101	515
1980	46	397	160	603
1985	41	477	291	809
1987	48	486	350	883

In some areas of the world, such as the southern United States, Australia, New Zealand and South America, wood from genetically improved trees is now being harvested, however, it will not be available in large quantities until after the turn of the century. In the southern United States virtually all plantation grown wood will be from genetically improved trees by 2015. The worldwide trend will be very similar.

IMPACT ON WOOD QUALITY

The next logical question is, "What will the wood of the genetically improved trees be like?". In most cases, it will be different from the wood of natural stands. This is not because of the impact of genetics, but because of the impact of plantation management. Even though the area in plantations will be only a small portion of the total forest area they will be so much more productive and accessible that they are likely to provide a substantial portion of the world demand for wood by the year 2025.

Most plantations, at least in the United States are grown on rather wide spacings with competition control and in some cases, fertilization. As a consequence, the trees will have a very large proportion of juvenile wood with short fibers, low specific gravity, high lignin content and a high amount of compression wood. Selection for high specific gravity, good form and smaller branches will alleviate the problems somewhat, but certainly not enough to make up for it.

Table 8: Worldwide planting of the southern pines (McDonald and Krugman 1986)

Continent or region	Seedling production	Area planted	Seedling output
	(thousands)	(ha/yr)	(%)
North America			
USA	1,500,000	1,000,000	65
Others	*	*	*
Central America and the Caribbean			
Cost Rica	2,000	1,100	< 1
Others	*	*	
South America			
Argentina	44,000	21,000	2
Brazil	230,000	130,000	10
Columbia	50	30	< 1
Uruguay	5,000	3,000	< 1
Venezuela	35,000	20,000	2
Others	*	*	*
Subtotal	314,050	174,030	14
Africa			
Republic of South Africa	15,000	10,000	1
Tanzania	375	188	< 1
Zimbabwe	350	260	< 1
Others	*	*	*
Subtotal	15,725	10,448	1
Asia Minor-India	*	*	
East Asia-Pacific			
Australia	6,350	3,700	< 1
PRC**	425,000	250,000	19
Fiji**	13,500	7,500	1
Malaysia**	3,000	1,500	< 1
Philippines**	12,500	7,000	< 1
Others	*	*	*
Subtotal	460,350	269,700	20
Total	**2,292,125**	**1,455,278**	**100**

*Small Amounts.

**Seedling production and hectares planted in PRC, Fiji, Malaysia, and the Philippines are estimates.

Actual values could range from ± 25 percent of the figures shown.

Table 9: Worldwide reforestation in the 1980's (Anon 1988)

Region	Area reforested Annually
	(Thousand hectares)
Africa	196
N. and Central America	2528
S. America	416
Asia	5649
Europe	1031
USSR	4540
Oceania	114
Total	**14,474**

Zobel (1981) made the following observations on the wood of fast-grown conifers. Their wood will have low cellulose and high hemicellulose yields when pulped; their chemical requirements and overall cost of pulping will be greater; solid wood products will be weaker and will be less stable. On the other hand wood from fast-grown conifers is highly suitable for ground wood and thermo-mechanical pulps.

Many of the fast-grown plantations in the tropics will consist of Eucalypts. Their growth potential is unbelievable and as technology improves the wood is being used for an increasingly wide range of products. Zobel (1981) indicates that paper bags, newsprint, and numerous other paper products are now made from pure Eucalyptus pulp. As in many hardwoods juvenile and mature wood in Eucalypts are fairly similar and the quality of fibers from young plantations is not very different from that of older ones.

Table 10: Seedling production and percent of genetically improved trees from 1956 through 1986 (Lantz 1988)

	1956	1966	1976	1986
Seedling production (millions)	591	519	878	1629
Percent genetically improved	-	-	27	91

Although breeding for wood quality is usually secondary to breeding for growth rate, there are some spectacular success stories. Ikemore (1986) e.g. describes the program of Aracruz Florestal in Brazil, where it has been possible through clonal selection and propagation to increase the growth rate of Eucalyptus from less that 20m^3 ha^{-1} yr^{-1} to almost 70m^3 ha^{-1} yr^{-1}, while changing the basic density from .48 to .52. She also found clonal differences in pulp yield from .51 to .57.

In New Zealand, some interesting work is being done with multinodal versus long internode selections in radiata pine. It is not clear yet whether the long internode variety will be economically viable (Shelbourne et al 1987).

In conclusion it needs to be emphasized that plantation-grown wood is different, but not necessarily better or worse than wood from natural stands. Much depends on the product that is to be made from such wood. The silvicultural regime of the plantations also has a major impact. By planting the trees at closer spacings, periodic thinning and growing the trees to longer rotations, the properties of the final product can be greatly modified. Plantation-grown genetically improved wood has a major asset working for it and that is its uniformity. By growing wood from one genetic source at one spacing and one rotation age it is possible to produce a highly consistent uniform product. The value of this is already evident in the eucalyptus pulp produced in Brazil which is rapidly finding a place in the world market, because of its desirable properties and consistent quality.

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IMPACT ON FUTURE FIBRE RESOURCES OF WOOD QUALITY ASSESSMENTS IN THE PULP AND PAPER-MAKING INDUSTRY

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SUMMARY

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Recent evidence from researchers in Europe have indicated that individual trees can be sampled for their pulping properties by the removal of small quantities (5-50g) of wood at about breast height (1.3m above ground). Work began at Sappi's Enstra Research and Development Centre in 1985 to develop techniques for local conditions. Since that time, individual trees of pines and eucalypts numbering 400 and 900, respectively, have been sampled for pulping. Large differences between and within families have been observed for pulp yield, kappa number, as well as the indices of tear and burst. More recently, heritabilities for these traits in *Eucalyptus grandis* Hill ex Maiden have indicated a strong degree of genetic control suggesting that selection and breeding for these traits will be successful.

Keywords: Tree improvement, pulp yield, wood density, tear index

INTRODUCTION

There are numerous references in the literature to indicate that pulp and paper-making properties can be predicted from wood traits such as gravimetric density (Barefoot et al., 1966; Ong, 1978; Burley and Palmer, 1979; Corson, 1984; Kibblewhite, 1984; and van Buijtenen, 1987) or anatomical characteristics (Barefoot *et al.*, 1970; Goodwin-Bailey, 1989; and Wright and Burley, 1990). However, this has not been found with selected trees in a tree breeding programme in South Africa. For instance, Wright (1987a) found that for fifteen trees of Pinus sp. no correlations between densitometric density and pulp and paper-making traits accounted for more than 50 per cent of the variation. In fact, high wood density in the pines can be associated with lower burst index and breaking length (Burley and Palmer, 1979; and Wright, 1987a). High wood density in *Eucalyptus grandis* Hill ex Maiden has been found to be negatively and significantly correlated with pulp yield presumbably because the higher wood density is comprised of lignin and extractives (Clarke, 1990). While wood density is certainly important to determine the dry tons of fibre produced per hectare per annum it has been over emphasized in some breeding programmes especially since methods are available to determine directly the pulp and paper-making traits for specific end users.

The correlations of pulp and paper-making traits with gravimetric density for pines and eucalypts included in the Sappi tree breeding programme are given in Table 1 (Wright, 1987a; and Clarke, 1990). Only for *Pinus caribaea* var. *hondurensis* Barr. and Golf. are the correlations with gravimetric density large enough to allow the improvement of kappa number and tear index by selecting for wood density. With the exception of *P. caribaea* var. *hondurensis*, selecting for gravimetric density in these species would not be effective in improving any of the pulp and paper-making triats evaluated here. It is possible that trends for a species do not hold true for selected trees within a species. The data presented here are not intended to reflect trends for a species or for sites that were not tested. The implications are that wood density is necessary to calculate kilogrammes of fibre per tree and per hectare. Wood density should not be used to screen trees or included directly in a selection index unless the corelations with pulp and paper-making traits are acceptable.

Table 1. Phenotypic correlations of pulp and paper-making traits with gravimetric density of pines and eucalypts in the Sappi tree breeding programme. Correlations followed by a *, ** or *** are significant at the 0.05, 0.01 or 0.001 levels, respectively.

Species	df	Pulp Yield	Kappa Number	Tear Index	Burst Index
P. patula ssp. *tecunumanii*	53	-0.132	0.069	0.304	-
P. elliottii	41	-0.172	-0.279	0.385*	-
P. caribaea var. *hondurensis*	24	-0.370	-0.703***	0.752***	-
Pine hybrid	22	-0.337	-0.392	-0.188	-
Pinus sp. (Transvaal)	20	-0.145	-0.030	0.533*	0.006
Pinus sp. (Zululand)	14	-0.547*	-0.078	0.503*	-0.579*
E. grandis	202	-0.244**	0.225**	-0.381***	-0.277**

Numerous references to micropulping can be found in the literature (van Buijtenen *et al.*, 1961; van Buijtenen *et al.*, 1968; and Manville and Hunt, 1977). Both Palmer (1985) and Janin (1981) developed techniques to pulp small (5.0-50.0g) quantities of wood removed from standing trees with an acceptable degree of precision and repeatability. Thus individual trees can be assessed for their pulp and paper-making ability. Trees that are superior for volume, pulp and paper-making traits can be retained for the collection of seed or scion material since the sampling procedure normally does not result in the mortality of the tree. Work at Sappi's Enstra Research and Development Centre began in 1985 to determine if techniques similar to those of Palmer could be developed for local conditions. This paper describes the development of these techniques and their likely effect on future fibre resources for Sappi and the region as a whole.

DEVELOPMENT OF TECHNIQUES TO ASSESS STANDING TREES FOR PULP AND PAPER-MAKING POTENTIAL

Few of the references to micropulping have indicated whether this technique gave good correlation to pulp from the whole tree. Palmer (1986) found that micropulping of wood samples (60.0 g) from *P. patula* Schiede and Deppe were significantly and positively correlated with full-scale (1.0kg) results for total pulp yield, kappa number, tensile index, stretch, tensile energy absorbed, tear index, burst index and fold when the pulps were beaten for the same length of time. Similar results have been found for micropulping of pines in South Africa

(Wright, 1987a; Wright *et al.*, 1989). These significant correlations between micropulping and full-scale results for pines indicate that samples removed at breast height give a good indication of the paper-making potential of the tree being sampled.

The present micropulping technique uses standard kraft cooking procedures (Table 2). Wood is removed at breast height from standing trees in the form of increment cores of 25mm or 12mm diameter and sufficent cores are taken to give an air dried weight of at least 100.0g. These cores are chipped to a uniform thickness of about 3mm. The cores and chips are stored in a controlled temperature (25°C) and humidity (50%) room. A small quantity of chips (3.0g) are used to determine the moisture content prior to pulping. These chips are not pulped. The pulp is screened using a mesh screen. Three pulp samples of about 10g each are removed from the washed and screened pulp for the determination of consistency which is necessary to determine the yield of pulp. The kappa number is determined from 0.5g of bone dry pulp. The remaining pulp (12.0g) is beaten in a microbeater which is similar in function to a PFI mill. A total of five handsheets are made and these are used to determine the paper strength properties. Only one beating point is evaluated. The most important traits for pines are total pulp yield, kappa number and tear index. A derived value, kilogrammes of fibre per tree, is the product of volume, gravimetric density and percent pulp yield. If the kappa number and tear index are acceptable the kilogrammes of fibre per tree is the main trait of interest.

Table 2. Kraft pulping conditions.

Max. Temp., (°C)	170
Time to 170°C, min.	110
Time at 170°C, min.	60
Liquor:wood	5.4:1
Active alkali, % as Na_2O	22
Sulfidity, %	26

Typical results for our micropulping technique are given in Table 3. The trees sampled were ten years of age and were produced by control cross pollination of *P. elliottii* Engelm. and *P. caribaea* var. *hondurensis*. There is a considerable range of values for all of the traits presented indicating variation that can be exploited or avoided. Data in this form can be used to indicate the best trees to be used for vegetative propagation and for inclusion in seed orchards. Data for all of the traits were compared using the analysis of variance (Table 4). Families were not significantly different for any trait except for volume. This is in contrast to a trial of pine hybrids assessed at age 15 years where families were found to be significantly different ($p<0.01$) for tear index and total pulp yield (Wright, 1987b). The lack of significant differences between families is possibly due to relatedness since the eight families represent only three male and three female parents.

Table 3. Volume, pulp and paper-making traits from 24 pine hybrid selections. All traits assessed at ten years following planting.

Sappi No.	SAFRI Cross	Vol. (m^3)	Pulp Yield (%)	Kappa No.	Tear Index	Den. (kg/ m^3)	Kg Fibre/ Tree
PH1	E1XC29	0.42	40.1	31.4	23.4	457	77
PH15	E1XC29	0.51	43.5	26.4	11.7	453	100
PH22	E1XC29	0.46	43.2	25.5	12.6	481	96
	Mean	0.46	42.3	27.8	15.9	464	91
PH2	E7XC53	0.40	44.8	30.9	18.5	391	70
PH13	E7XC53	0.41	41.0	30.6	13.4	455	77
PH19	E7XC53	0.33	42.9	26.6	11.9	479	68
	Mean	0.38	42.9	29.4	14.6	442	72
PH3	E7XC29	0.43	44.1	30.3	15.5	415	79
PH10	E7XC29	0.54	42.8	29.1	12.0	457	105
PH18	E7XC29	0.50	41.2	24.3	12.7	471	97
	Mean	0.49	42.7	27.9	13.4	448	94
PH4	E1XC53	0.38	40.4	29.3	13.2	416	65
PH12	E1XC53	0.59	42.6	25.4	12.1	452	114
PH21	E1XC53	0.41	40.2	28.0	11.0	418	69
	Mean	0.46	41.1	27.6	12.1	429	83
PH5	E30XC29	0.45	43.2	27.6	15.1	455	88
PH9	E30XC29	0.43	40.1	30.3	11.9	448	77
PH23	E30XC29	0.48	37.8	28.4	9.7	466	85
	Mean	0.45	40.4	28.8	12.2	456	83
PH6	E7XC18	0.41	42.3	31.2	11.3	477	84
PH16	E7XC18	0.43	42.4	29.8	12.6	453	83
PH24	E7XC18	0.30	41.3	30.6	11.0	482	61
	Mean	0.38	42.0	30.5	11.6	471	76
PH7	E1XC18	0.32	46.1	34.2	13.1	426	62
PH11	E1XC18	0.32	41.3	29.2	13.6	473	64
PH17	E1XC18	0.46	44.8	30.9	10.7	376	77
	Mean	0.37	44.1	31.4	12.5	425	68
PH20	E30XC18	0.43	40.9	28.9	11.3	457	80
PH8	E30XC18	0.48	41.1	28.0	14.6	420	83
PH14	E30XC18	0.54	42.5	27.2	12.9	496	114
	Mean	0.48	41.5	28.0	12.9	458	92
	Overall Mean	0.43	42.1	28.9	13.2	449	82
	Overall Min.	0.30	37.8	24.3	9.7	376	61
	Overall Max.	0.59	46.1	34.2	23.4	496	114

While the micropulping method allows for the assessment of pulp yield and tear index using standard laboratory methods a more rapid form of tree evaluation was sought. Recent research at Sappi (Birkett and Gambino, 1988) has indicated the potential of near infra-red reflectance spectroscopy (NIRS). Wood is collected as 5mm increment cores and assessed in powder form. For pines, Wright *et al.* (1990) found positive and significant correlations with standard laboratory techniques for total pulp yield ($r=0.668^{***}$) and cellulose content ($r=0.730^{***}$). This allows for non-destructive sampling of genetic and silvicultural trials since only three increment cores of 5mm diameter weighing approximately 5g are required.

Table 4. Analysis of variance of volume, pulp and paper-making traits from 24 pine hybrid selections. Mean square values followed by * are significant at the 0.05 level.

Source	df	Mean Square					
		Volume	Pulp Yield	Kappa Number	Tear Index	Density	Kg Fibre/ Tree
Blocks	2	0.007	2.40	16.16	27.16	993.3	307.2
Family	7	0.008	4.00	6.06	6.21	796.5	288.7
Residual	14	0.004	3.33	3.33	6.44	954.9	200.8

IMPACT ON FUTURE FIBRE RESOURCES OF WOOD QUALITY ASSESSMENTS IN THE PULP AND PAPER-MAKING INDUSTRY

Evidence from current research indicates that selection and breeding for improved pulp and paper-making traits is feasible. An increase of 1-2% in total pulp yield while maintaining paper strength properties appears likely for pines and eucalypts currently planted in South Africa. Ikemori *et al.* (1986) have obtained a two per cent increase in pulp yield for each generation of improvement in their hybrid eucalypt programme. Separate breeding lines for specific characteristics such as high tear or burst indices could be developed though this implies a commitment from land and mill management that is seldom seen in practice. The use of vegetative propagation to capture the gains of selecting and breeding for pulping traits should result in the greatest financial return on investment.

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NORMALIZATION OF STANDARDS FOR CONSTRUCTION TIMBER IN THE EUROPEAN COMMUNITY

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SUMMARY

If standards for construction timber are to support the use of timber in the face of competition by other materials they must clearly show builders, architects and engineers that timber is available in qualities which fulfill all requirements for and expectations of an attractive and safe building material.

The new European construction timber standards try to achieve this objective by both a system of strength classes as well as a system of appearance classes. Consumers thus have the option to select structural timber of a desired strength class which will meet either greater or lesser optical requirements as demanded for the specific end use.

Keywords: Timber quality, strength classes, appearance classes

BACKGROUND

In 1986 European community (EC) countries consumed 53.5 Mio m^3 of sawn timber, 41.5 Mio m^3 of which were softwood and 12 Mio m^3 hardwood. Only a little more than half of this amount, viz. 29.9 Mio m^3 was produced in the EC while the other half was imported, in particular from EFTA countries such as Scandinavian countries and Austria as well as from various Eastern European countries and North America. For some years many EC countries have been increasingly planting fast-growing hardwoods and softwoods in order to raise national wood production. Furthermore, for silvicultural and ecological reasons traditional hardwood species such as beech and oak are afforested to an increasing extent. Hence more hardwood timber for structural purposes will be available in the future.

In principle the available timber supply will consist of the following 5 different groups: Apart from central European softwoods with average growth rates and knot sizes, slow-growing "nordic" spruce and pine from parts of

Scandinavia and the USSR with narrow ring widths and small knot sizes as well as an increasing supply of fast-growing wide-ringed softwoods (e.g. Sitka spruce, maritime pine, Douglas fir); furthermore, traditional home-grown and imported hardwoods and fast-growing plantation hardwood, especially poplar.

This wide range of timber qualities meets a most heterogenous consumer market characterized by different building traditions, architectural preferences, economic conditions and builders' requirements within the various EC countries. Thus different regions in Europe use different timber cross-sections and lengths, from small and slim sizes similar to American dimension lumber to large cross-sections of 140 x 280 mm^2 and above, while lengths may vary between 4 m and much more than 12 m.

Construction timber is largely being used so that it does not remain visible in the finished structure, such as in sheathed walls and ceilings of timber frame structures or in non-accessible roof constructions. Usually few demands on appearance are being made on timber used in this way. However, there is a growing tendency towards timber structures in which the load-bearing components remain visible for architectural reasons, in residential buildings as well as in many non-residential public and industrial structures. These buildings show evidence that the decision to use wood is frequently based not merely on price considerations but on architectural quality, i.e. on individuality, attractiveness and quality of materials used.

If standards for construction timber are to support rather than obstruct the use of timber in the future, a third aspect will have to be considered: There is a high proportion of practising architects and engineers who do not have a sufficient understanding of timber as a material and its use in design. From this follows that they do not have the confidence to design in timber and therefore timber is rejected at the early stages of a project only due to lack of knowledge or information. This is probably one of the reasons for the limited use of timber as a major structural material: In Europe the market share for timber structures at present is not more than about 10 %. Moreover it is only 2 to 5 % for industrial buildings, the only part of the building industry considered to continue to have positive growth rates. Another aspect is the fact that even in its traditional fields of application timber in construction in Europe is subject to tough competition by the generally larger sized and more innovative concrete, steel and plastics industries.

REQUIREMENTS FOR CONSTRUCTION TIMBER STANDARDS

Standards for construction timber should be informative, easily intelligible and attractive for potential users. The definition of wood quality in the standards should clearly correspond to the requirements for and expectations of building materials generally entertained by architects and engineers. This is the precondition for construction timber being regarded as an architecturally attractive, safe and economically interesting building material and hence being considered at all in the material selection process.

To achieve a correspondence of available wood qualities to consumer demands the following four steps are required:

- identification of objective and subjective quality requirements for construction timber by analyzing consumer expectations and demands
- conversion of these quality requirements into measurable product properties such as strength, surface finish etc.
- correlation of product properties with wood properties such as knot ratio, spiral grain, density etc.and with processing techniques such as sawing patterns, drying, surface processing
- establishment of a system of classes based on these properties which will ensure that the individual classes represent consumer demands as regards quality and quantity.

BASIC CONCEPT OF CONSTRUCTION TIMBER STANDARDS

Based on the above relationships the concept for the new European construction timber standards was developed along the following lines:

- The introduction and use of a uniform grading rule would be uneconomic in view of the given variety of available timber with regard to origin, dimensions and qualities. Different grading rules will therefore be allowed to be used side by side to warrant optimum utilization of different wood species and origins.
- The great variety of different available wood species, wood species combinations and grading rules leads to a great number of possible grades, which confuses consumers and hence may prevent the use of timber. A system of consumer oriented structural timber classes is therefore being introduced into which all possible grades can be incorporated according to uniform rules. This set of classes enables consumers to select construction timber of desired quality with defined and guaranteed timber properties.
- For structural timber both a system of strength classes as well as a system of appearance classes is being developed. Consumers have thus the option to select structural timber of a desired strength class which will meet either greater or lesser optical requirements according to the specific type of structure.

The subject of strength grading and strength classes is being dealt with by CEN/TC 124; first drafts of standards have been elaborated.

CEN/TC 175 is responsible for appearance classification with meetings of corresponding working groups to be held in the course of 1990.

Although knots were a major determinant of visual lumber grade there is no direct linear relationship between knot size and visual grade. This results from the fact that an acceptable knot size for a given lumber grade is defined by the size of the lumber piece and by the location of the knot within the piece.

Lumber grade and value considerations of second-growth material will have to include the impact of juvenile wood on lumber drying and strength characteristics. Warp, particularly twist, was a major drying degrade factor with a strong tendency for warp to increase with increasing proportion of juvenile wood.

Of greater concern is the magnitude of potential grade and value reduction resulting from the reduced strength and stiffness of lumber with high proportions of juvenile wood. These results do not reflect the design values that could currently be assigned to random samples of visually graded lumber as typically marketed in British Columbia. Rather, they bring industry's attention to a potential value problem should there be a significant change in log sorting strategies, proportion of second-growth being harvested or a change in forest management strategy that increases the production of lumber of lower density.

There is a substantial proportion of the lumber from second-growth trees with high strength and stiffness properties that are not recognizable by means of visual grading. By contrast, machine stiffness rating systems provide a direct method of assessing the structural performance capability of each piece of lumber. In a similar sense, conventional kiln-drying schedules and practices may result in appreciable drying degrade in second-growth Douglas-fir lumber containing a high proportion of juvenile wood. Methods have been developed elsewhere in the world to deal with similar drying problems and these should be examined to develop a cost-effective means of reducing degrade losses in this material.

Perhaps one of the greatest values in the information obtained in this study is the recognition of potential quality problems so that methods can be developed to deal with them effectively before this type of wood becomes a significant component of the harvested coastal Douglas-fir resource. The results should suggest ways in which second-growth can be converted, graded or marketed in order to realize its highest potential value.

Conversion to Pulp

If the second-growth coastal Douglas-fir resource or sawmill residuals from that resource are converted to kraft or refiner mechanical pulp certain observations can be made on the characteristics of those pulps based on the results of this study. Yields of both bleachable-grade and linerboard grade kraft pulps were consistently lower for juvenile wood relative to mature wood. Presumably due to interfiber bonding, the juvenile wood pulp had higher tensile and burst strength, a greater stretch and stress-strain factor than that from mature wood. On the other hand the juvenile wood pulp was substantially lower in tear strength than the mature wood pulp. The wide ranging properties of bleachable-grade kraft pulps made from the different components from the second-growth Douglas-fir resource were predictable on the basis of wood or chip density, fiber length and fiber coarseness.

An increase in the proportion of juvenile wood will adversely affect the tear index of kraft pulps of coastal Douglas-fir to a point where they are more comparable with the tear strength of other Canadian softwoods. This drop in tear is offset to some degree by increased tensile strength and sheet density. In short, the future resource can be expected to produce a more balanced kraft pulp. It appears that there is the potential for an increased range of properties from kraft pulps of second-growth Douglas-fir which offers a broader range of utilization options. Other softwoods may not be capable of providing a comparable range in properties. Fibers from mature wood refiner mechanical pulps were longer and coarser than those from juvenile wood pulp. As a result mature wood pulps were stronger in both tensile and tearing strength.

It has been found that the properties of refiner mechanical pulps can be predicted and explained primarily on the basis of fiber length, fiber strength and Klason lignin content of the wood. Wood density is also important, but unlike the models developed for kraft pulps, plays a less dominant role. Consideration of available options for utilization of second-growth Douglas-fir refiner mechanical pulps suggests that there is a good potential for the production of mechanical pulps with a distinctive range of properties.

Evaluation of Silvicultural Strategies

The second major contribution of this study has been the development of a model called SYLVER which can relate silvicultural strategies to standing yield, product recovery and financial return. Initial validation shows that SYLVER has successfully integrated the results of the Task Force studies into a system sensitive to environmental variables, silvicultural practices, wood properties, product quality, financial return and management opportunities. The flow of information from the Task Force Project to the SYLVER model is illustrated in Figure 2.

The model shows that the financial return from investments in silviculture are very sensitive to planting density and harvest age when conventional visual grading procedures are applied. The type and timing of optimum silvicultural practices depends on site quality, hauling distance, discount rate, costs, prices and many other factors which may be altered by the user. Recognition of the different properties of juvenile and mature wood tends to increase the planting density and extend the rotation age. Defining the magnitude of these effects provide the forest industry with some sense of the potential value impacts against which the investments in either technological or biological solutions to the problem can be compared.

As part of the effort to remain competitive on the world market Canada's forest industry must maintain a high quality resource which will permit the greatest flexibility in the manufacture of a variety of high quality value added products. Information of the type gathered from this integrated research effort should go a long way in helping to achieve that goal.

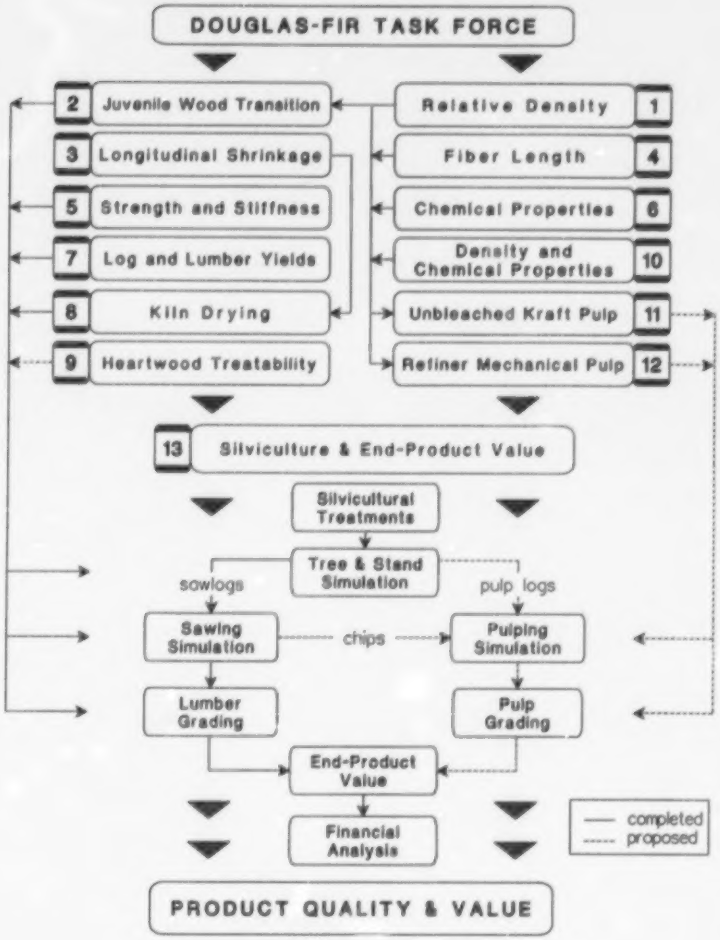
DOUGLAS-FIR TASK FORCE
2 Juvenile Wood Transition
1 Relative Density
3 Longitudinal Shrinkage
4 Fiber Length
5 Strength and Stiffness
6 Chemical Properties
7 Log and Lumber Yields
10 Density and Chemical Properties
8 Kiln Drying
11 Unbleached Kraft Pulp
9 Heartwood Treatability
12 Refiner Mechanical Pulp
13 Silviculture & End-Product Value
Silvicultural Treatments
Tree & Stand Simulation
sowlogs
pulp logs
Sawing Simulation
chips
Pulping Simulation
Lumber Grading
Pulp Grading
End-Product Value
Financial Analysis
completed
proposed
PRODUCT QUALITY & VALUE

Fig. 2 Information flow between Douglas-fir Task Force projects

January 1, 1990

RELATIONSHIPS BETWEEN TREE DECLINE AND PATTERNS OF FOG IMPACTION ON LEAF SURFACES

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FDC: 425.1: 425.3: 181.45

Using a fluorescent dye marker and ultrasonic fog generator, patterns of fog impaction on leaf surfaces have been studied for certain tree and herbaceous species. The pattern of deposition is species specific and ranges from a uniform droplet deposition over a leaf surface to site specific deposition. In red spruce, for example, deposition in still air is exclusively on the surface of the waxy plug filling epistomatal chambers. Thus, successive polluted fogs with no intervening rain contribute to a selective concentration of dry deposition over epistomatal chambers. Scanning electron microscopy reveals differentially enhanced degradation of epistomatal waxes compared to epidermal cell waxes. Differences in fog deposition patterns and leaf metabolic activity are discussed in relation to possible biophysical mechanisms and plant sensitivities to acidic fog.

EFFECTS OF AIR POLLUTION ON THE PINUS THUNBERGII FORESTS AROUND THE INDUSTRIAL AREAS IN KOREA

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FDC: 425.1: 425.3: 181.45: 174.7 Pinus thunbergiana Franco: (519)

This research was performed to investigate the effects of air pollution in the *P. thunbergii* forests around the industrial areas, and the environmental factors, contents of soluble sulfur in needles, variation of forest vegetation and changes of growth rings were examined versus the distance of pollution sources. The results obtained were as follows. There was significant correlationship between the sulfur contents in the soil and soil pH at 1% level. The contents of soluble sulfur in needles ranged from 0.13% to 0.25% and were high near the pollution sources. As regards variation of forest vegetation, the number of species was lowest in the vicinity of pollution sources with 7 species and highest with 20 species in the farest sites. There was significant correlationship between the contents of soluble sulfur in needles and the number of species and species diversity at 5% and 1% level, respectively. The importance value of each species was low near the pollution sources but *Quercus* species showed high values in all sites. As regards changes in growth-ring structure the width and density extremely decreased 2-3 years after the beginning of the operation of the factories in the vicinity of the pollution sources.

THE VULNERABILITY OF ADULT PICEA RUBENS IS RELATED TO SITES VARYING IN ATMOSPHERIC DEPOSITION OF POLLUTANTS

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FDC: 425.1: 425.3: 181.45: 416.4: 174.7 *Picea rubens* Sarg.

Soil mineral imbalances due to air pollution can cause nutrient deficiences leading to decreased wood production. Increases in tree vulnerability are hypothesized to result from these nutrient deficiences mediated through decreased wood production and reduced responsiveness of sapwood to stress. The following experiment was established to test the hypothesis that the degree of tree vulnerability is related to forest sites that differ in the level of deposition of air-borne pollutants. Vulnerability was measured as the stemwood response of *P. rubens* two years following standardized wounding.

Sites selected in the northeastern U.S. included those with a high degree of atmospheric deposition and forest damage (e.g. Mt. Abraham, Vermont) and those with a low degree (e.g. Beddington, Maine). In June, 1986, six trees representative of those in the canopy at each site were wounded. Each tree received a single wound consisting of the removal of a rectangle of bark, phloem, and associated vascular cambial tissue. Wound surfaces were all 1 m in vertical extent and extended horizontally for one-quarter of the tree circumference. In 1989 wounded trees were felled and sectioned. Four transverse stemwood planes were measured from each tree: 5 cm below the bottom of the wound, through the middle of the wound, 5 cm above the top of the wound, and 50 cm above the top of the wound. Each plane was traced into sheets indicating areas of sapwood, heartwood, blue stain, and visibly decayed wood. The amount of sapwood lost due to transformations induced by wounding was estimated by measuring SW thickness distal to the wound surface for each plane and added to each tracing. Vulnerability indices, calculated as the proportion of the areas of SW lost: SW present for each stemwood plane were statistically compared. Vulnerability indices and amounts of blue stain for Mt. Abraham were significantly greater than for Beddington. The measured areas and indices were not related to the position of the plane relative to the wound. Also, total transverse area, sapwood basal area, and visible decay were not related to site.

Previous work predicting the relationship of vulnerability index to site considered that the relationship could be mediated by differences in SW basal area. These analyses indicate that even when SW basal areas are similar, the dynamic response that serves to limit the extent of damage due to a wound is still related to sites associated with different levels of atmospheric deposition. We predict that given a longer incubation time, patterns of amounts of decayed wood would parallel amounts of blue stain and be associated with site.

MONITORING OF AIR POLLUTION EFFECTS IN SILVER FIR BY ELECTRICAL RESISTANCE MEASUREMENTS

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**Department of Forestry, Biotechnical Faculty, Ljubljana, Yugoslavia

FDC: 425.1: 425.3: 174.7 Abies alba Mill.--015.25

Two representative forest stands of the association Abieti-Fagetum dinaricum (subass. div.: hacquetietosum, galietosum odoratae, dentarietosum & asaretosum) in Slovenia (NW Yugoslavia) were sampled. In 462 test silver firs (Abies alba Mill.) the "horizontal" electrical resistance (ER) at breast height and in 8 silver firs the "vertical" ER at several levels of living tissues were determined. ER measurements were made with the conditiometer (Bollmann-Elektronik Systeme, FRG) and with double needle noninsulated stainless steel electrodes, 11 mm apart.

In measuring the "horizontal" ER the electrodes stopped at the latewood of the previous year. The "vertical" ER was determined at four locations: (1) peripherial, (2) central, (3) innermost part of nonconducting phloem and (4) cambial zone, with the depth of electrode penetration of 7 mm.

Generally healthy, dominant trees with a wider cambial zone, current xylem increment and living bark showed lower, and diseased or healthy suppressed trees with narrower living tissues showed higher "horizontal" and "vertical" ER.

ER also changes with season due to the variable width of xylem and phloem increment and cambial zone (vascular cambium + undifferentiated derivatives) as well as in accordance with hydrothermic conditions of the current growth period.

The method is very sensitive. The ER readings are significantly correlated with the state of health or cenotic status (dominance, suppression) of individual trees.

THE CONTROL OF WOOD FORMATION IN RING-POROUS VS. DIFFUSE-POROUS TREES: A NEW HYPOTHESIS.

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FDC: 161.4: 811.41: 811.42

The new "limited growth hypothesis" (Aloni 1990) explains the different hormonal mechanisms which control earlywood and latewood differentiation in ring- versus diffuse-porous tree species. According to this hypothesis, continuous selective pressures in limiting environments finally resulted in the development of the specialized ring-porous wood that maximized the efficiency of water conduction. Supporting evidence shows that the selection for ring-porous wood has led to a decrease in the intensity of vegetative growth, accompanied by reduced levels of growth regulators. The latter was followed by an increase in the sensitivity of the cambium to a relatively low levels of stimulation. These physiological changes created the special internal conditions that enabled the differentiation of very wide and long earlywood vessels during a limited period of time during spring, in the ring-porous trees (Aloni, R., 1990: Wood formation control in deciduous hardwood trees. In: Physiology of Trees, ed., A.S. Raghavendra, John Wiley & Sons, New York, in press).

ONTOGENIC CHANGES IN CAMBIAL GENOME SIZE IN ABIES BALSAMEA

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FDC: 168: 181.21/.22: 174.7 Abies balsamea Mill.

The genome size of cambial cells in Abies balsamea varies during ontogeny. As revealed by spectrophotometry of Feulgen-stained nuclei, the genome size increases with cambial age and fluctuates during the annual cycle of cambial activity and dormancy. Genome size is maximal before the onset of cambial activity (when trees are frost hardy and have high growth potential), decreases quickly during the growing season (when trees lose their frost hardiness), attains the minimum at the beginning of rest and increases during the rest-quiescence transition (when frost hardiness and growth potential also increase). Thus, changes in nuclear DNA content might be causally related to changes in cambial growth potential and/or cambial frost hardiness. Since these physiological processes are environmentally cued, we investigated how manipulating temperature and photoperiod would affect them individually. On three different dates when the cambium was in a particular physiological stage, 6 year-old potted trees were transferred from nursery conditions to a growth chamber having either constant warm (20°C) or cold (+5°C) temperature coupled with either short (8 h) or long (8 h plus 1 h night light break) photoperiod. After nine weeks genome size was measured with the Feulgen procedure, cambial frost hardiness was assessed as cambial survival after exposure to -40°C and cambial growth potential was determined as the number of fusiform cells produced by the cambium following the apical application of IAA to disbudded cuttings placed in environmental conditions optimal for growth. The same variables were also measured in trees left outdoors. In the outdoor trees, genome size fluctuated seasonally, as observed previously, and was positively correlated with cambial growth potential and frost hardiness. In the growth chamber trees, treatment effects depended upon the time of year that the trees were placed in the chamber. In the fall (resting cambium), temperature did not influence genome size, while long photoperiod tended to decrease it. In contrast, cold temperatures increased both cambial growth potential and frost hardiness. In early spring (quiescent cambium), cold temperature maintained the initial high DNA content, high growth potential, and to a lesser degree high frost hardiness, whereas short photoperiod plus cold temperature increased DNA, growth potential, and frost hardiness. In the summer (active cambium), cold temperature induced a decrease in the DNA level and an increase in growth potential and frost hardiness. Since no consistent correlation between cambial genome size and or cambial growth potential or cambial frost hardiness was found, we conclude that the genome size does not directly control either process.

PHYTOHORMONE REGULATION OF SECONDARY XYLEM DEVELOPMENT

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FDC: 161.4: 811.18: 174.7

SUMMARY

Findings based on research conducted by myself concerning the intrinsic regulation of wood formation within conifers are reviewed. It is concluded that auxin has both direct and indirect roles in controlling cambial growth. Direct effects of auxin include maintenance of the fusiform morphology of cambial cells and promotion of primary-wall radial expansion in cambial derivatives which are on their way to becoming xylem cells. Auxin also appears to have the indirect effect of attracting other factors to stem locations where auxin is most concentrated. The research findings do not support the conclusion that auxin initiates tracheid differentiation nor that auxin controls the extent of secondary-wall formation occuring during xylem development. Cytokinins clearly interact with auxin in controlling lignification biochemistry; however, my findings appear to contradict the hypothesis that an auxin-cytokinin combination is the principal mechanism regulating tracheid differentiation, suggesting rather that there exists an unidentified tracheid differentiation factor which is produced by conifer leaves. The little so far known about the roles of abscisic acid, ethylene and gibberellins in regulating xylem development is discussed briefly.

INTRODUCTION

Relations between endogenous phytohormones and cambial growth, and the effects of exogenous (synthetic) phytohormones on secondary xylem development in trees have both been reviewed several times over the last decade (Little and Savidge 1987; Savidge 1990b, 1988b, 1985; Savidge and Wareing 1981b). This paper summarizes findings in these areas with conifers that have been reported by myself and my associates since 1981.

AUXIN AND ABSCISIC ACID

Auxin (indol-3-ylacetic acid, indole-3-acetic acid, IAA) has been chemically characterized by combined gas chromatography - mass spectroscopy (GC-MS) in cambial tissues from 32 tree species (Little and Savidge 1987; Savidge 1990a). The data so far gathered suggest IAA is of general occurrence in stems of woody plants.

As shown in Fig. 1, during winter dormancy endogenous IAA was readily detected by GC-MS in the cambium of conifers. These data from disbudded-defoliated , girdled, and untreated (control) *Pinus contorta* on a Welsh site suggest that auxin is exported from buds and mature leaves and is transported basipetally during the dormant period (Savidge and Wareing 1982). It is of interest that IAA also was found in abundance by GC-MS in *Larix decidua* cambium but was scarcely detectable in cambia of deciduous hardwoods during the winter months (Savidge and Wareing 1982).

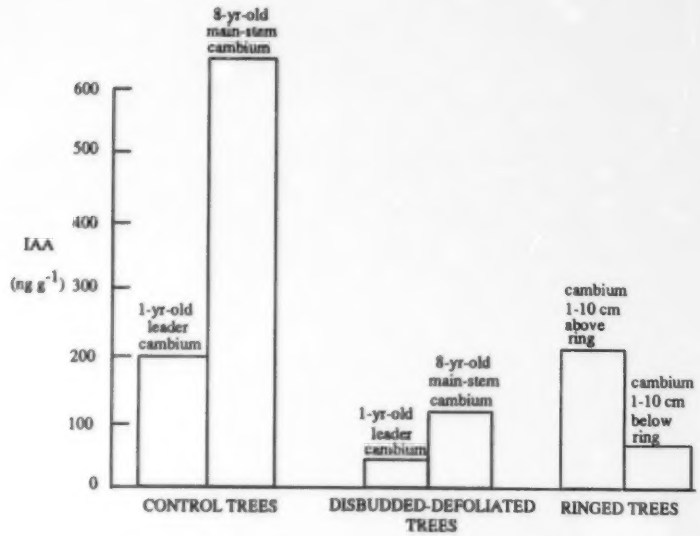


Fig. 1. Endogenous IAA content of the dormant cambium of *Pinus contorta* (10-yr-old trees) in early November. Disbudding defoliating and ringing were done in late October.
(After Savidge and Wareing 1982).

All available data seem to support the theory that auxin biosynthesis and export occur in and from, respectively, the foliated portions of the tree and that polar auxin transport from shoots toward roots occurs through the cambium (Savidge and Wareing 1981b; Little and Savidge 1987; Savidge 1985, 1989, 1990b). *In vitro* studies on the conifer cambium revealed that in the absence of a continuing source of exogenous auxin applied to the apical ends of stem segments, the axially elongated fusiform shape of cambial cells disappeared; i.e. the entire cambial zone de-differentiated into axial parenchyma (Savidge and Wareing 1981b; Savidge 1983). In other words, it appears that the very existence of the cambium in stems of conifers is not epigenetically constrained within the cambial genome, rather is determined by the continuing export of auxin from the leaves and shoot apices to, and its basipetal transport through, the cambium. If this interpretation is correct, it follows that auxin biosynthesis and export during dormancy in conifers fulfil an important physiological function, namely maintaining the vascular cambium as the lateral meristem that it is.

Seasonally, highest endogenous auxin content in the cambial region was found in late spring and early summer in association with shoot growth and leaf development, as shown in Fig. 2.

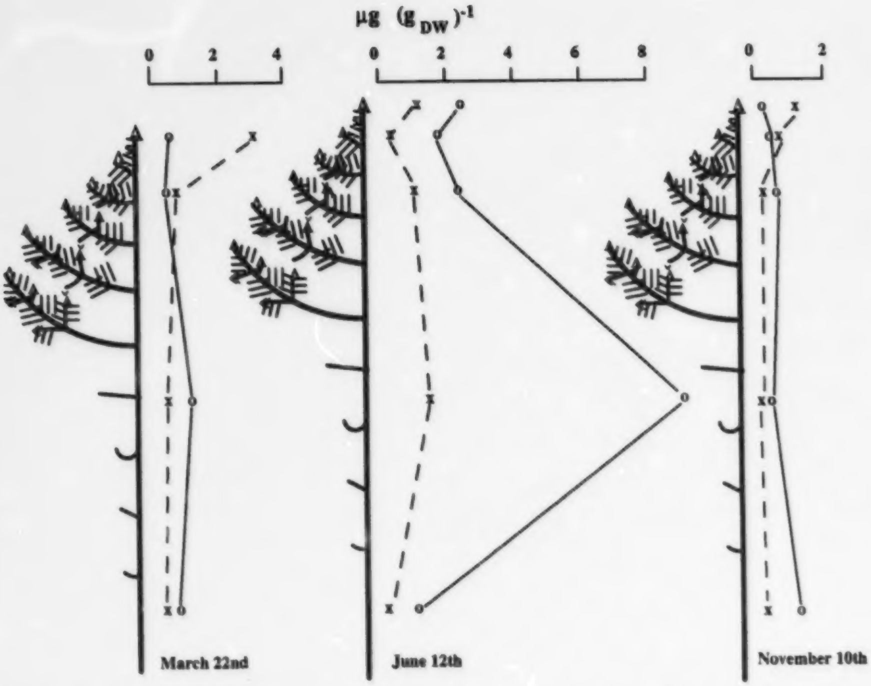


Fig. 2. Endogenous IAA (o ——o) and ABA (x — —x), as measured by GC-MS and GC, respectively, in the cambium of *Pinus contorta* before (March 22), during (June 12), and after (November 10) a season of growth. The cambium was active except at the tree base on June 12th, and was dormant throughout on the other two dates. (After Savidge and Wareing 1984).

In this study (Fig. 2), it was anticipated that the cambium's content of abscisic acid (ABA), a supposed inhibitor of cambial growth, would change inversely to that of auxin as the cambium changed from quiescence to growth to rest; however, as Fig. 2 shows, this was not found to be the case. The ABA content increased in association with cambial growth and did not increase, rather decreased, during cambial dormancy. ABA therefore does not appear to be the factor initiating cambial dormancy in *Pinus contorta*. Nor does exogenous ABA have any apparent inhibitory effect on auxin-promoted cambial growth in conifers (R. A. Savidge and M. Leitch, unpublished data); however, in one investigation evidence that exogenous ABA did have an inhibitory effect on tracheid differentiation was observed (Savidge 1983). In non-woody species, ABA has been found to have a regulatory function in promoting phloem unloading; however, this possibility remains to be investigated in trees.

Because of the difficulty associated with isolating the cambium during dormancy, it remains unknown how IAA is distributed within the cambial region during the inactive period. But as shown in Fig. 3, during the active period of growth, when the cambial zone could be separated by bark peeling from radially enlarged derivatives in the process of xylem development, IAA was found to be most concentrated in the region of developing xylem.

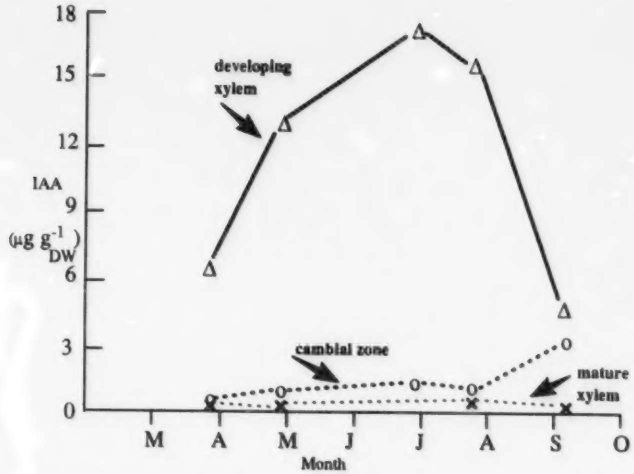


Fig. 3. Seasonal variation in endogenous IAA in the cambial region of *Pinus contorta*, as determined by GC-MS. (After Savidge *et al.* 1982).

Attempts by myself (R. A. Savidge, unpublished data) and others (C. H. A. Little, personal communication) to demonstrate that the remarkably high IAA content found in association with xylem development was because IAA biosynthesis was occurring in that region were unsuccessful. The fact that there was virtually no detectable IAA in the transpiration stream, i.e. in mature xylem (Fig. 3), precludes the possibility that developing xylem obtained its IAA supply from the roots. It therefore is concluded that IAA from extending shoots and developing and mature leaves must become non-uniformly distributed toward the centripetal side of the cambial region as IAA moves down the stem.

The non-uniform cambial IAA distribution shown in Fig. 3 is hardly to be expected because it is well established that IAA is readily oxidized by peroxidases. These enzymes are present in abundance in support of lignification during xylem development (Savidge 1989). Possibly IAA accumulates in developing xylem because IAA is protected from peroxidase degradation through some form of sub-cellular compartmentalization. Alternatively, it could be that the IAA content within the zone of developing xylem itself varies in inverse relation to peroxidase distribution.

As shown in Fig. 4, in conifers there was little if any histochemically demonstrable peroxidase activity in cambial derivatives in the process of primary-wall radial expansion, the activity of peroxidase was restricted to differentiating tracheids in the processes of secondary wall formation and lignification (R. A. Savidge, unpublished observations). Thus, it may be that IAA accumulates in the region of primary-wall radial expansion to be degraded in the region of lignification. If this latter hypothesis is correct, it follows that the high IAA content in 'developing xylem' shown in Fig. 3 must in actuality have been even higher within those radially expanded cells which were not yet in the lignification phase of tracheid differentiation.

That IAA promotes primary wall growth has frequently been demonstrated in non-woody plants, and the data of Fig. 3 can be interpreted in this light. The high IAA content in the region of xylem development correlated with the wide radial diameters achieved by differentiating cambial derivatives during earlywood formation, and the decline in IAA content occurring later in the season parallelled a reduction in tracheid diameter in association with latewood formation at that time. The relatively low IAA content in the cambial zone throughout the growth season is in agreement with both ray and fusiform cells of the cambial zone being of narrow radial dimension.

In the study shown in Fig. 3, the grand period of cambial growth began in late April. Despite a high frequency of cell division, IAA content of the cambial zone showed no notable increase over that of the dormant cambium nor that of the less active cambium later in the growth season. These data suggest, therefore, that the IAA content of the cambium may not normally be the factor limiting the rate of meristematic activity in the cambium. On the other hand, as shown in Fig. 2, during the active growth period the highest IAA content in the stem was near the base of the living crown where maximum cambial growth predictably occurs, suggesting that an axial gradient in IAA content of the cambium could be a factor controlling cambial growth rates.

Studies with exogenous auxin have provided further reason to question the precise role of endogenous IAA in promoting cambial cell division activity. When the cambium, sandwiched intact between mature phloem and xylem, was isolated from the tree stem and grown *in vitro*, the addition of auxin to the culture medium was unnecessary for the occurrence of cell division activity within the cambium; however the plane of cell division was abnormal, becoming true transverse (Savidge 1983). Upon addition of auxin to the culture medium, these true transverse cell divisions did not occur but neither did any other plane of division; i.e. cambial cell division activity was not promoted by auxin (Savidge 1983).

Findings based upon applications of exogenous IAA to cuttings *in vivo* has raised additional questions. Applied to apical ends of disbudded-defoliated hardwood cuttings, IAA clearly promotes prosenchyma development; however, cambial cell division activity is much more apparent in response to exogenous gibberellic acid (GA_3) when applied either alone or in combination with auxin (Savidge and Wareing 1981b). In conifers, exogenous auxin promoted very limited cambial activity in disbudded-defoliated cuttings that were two or fewer years old and, as explained in greater detail below, had no promotory effect on cell division activity in older ages of cambium (Savidge 1983).

***Pinus strobus* L.**

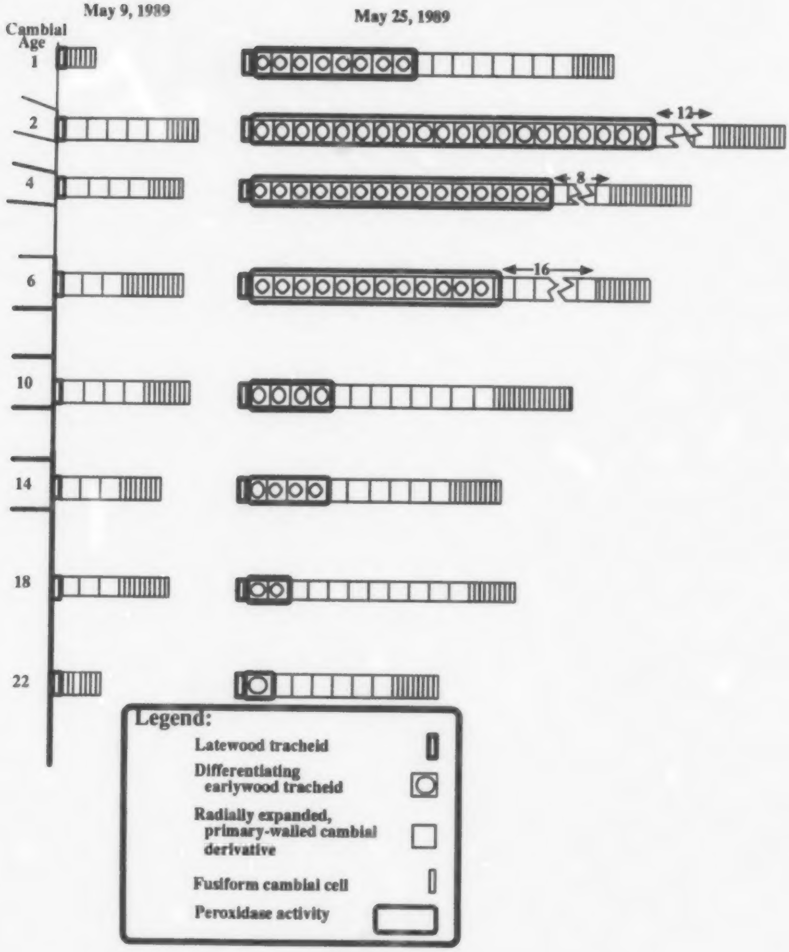

May 9, 1989
May 25, 1989
Cambial Age
1
2
4
6
10
14
18
22
12
8
16
Legend:
Latewood tracheid
Differentiating earlywood tracheid
Radially expanded, primary-walled cambial derivative
Fusiform cambial cell
Peroxidase activity

Fig. 4. Patterns of cambial reactivation, xylem development, and peroxidase activity in *Pinus strobus* at the beginning of the growth season. Peroxidase activity was determined histochemically using guaiacol and p-anisidine HCl reagents. (R. A. Savidge, unpublished data).

Yet another reason to question whether auxin actually promotes cell division in the cambium is apparent in Fig. 5. Exogenous auxin promoted cambial growth in the region immediately beneath the apical end of the cutting, and some cambial growth was also found at the cutting's basal end; however, there no cambial growth occurred in the intervening region. In 'control' cuttings, the only cambial response was de-differentiation of fusiform cambial cells into axial parenchyma, as described above. The concentration of auxin in the cambium of a cutting lacking buds and leaves and provided exogenous auxin can be assumed to be highest immediately beneath the site of auxin application, at the apical end of the cutting. Because of the polar (basipetal) transport nature of auxin, the auxin concentration at the cutting base presumably also became elevated. What the observations from this experiment seem to convey, then, is that while a continuing apical supply of auxin is needed to maintain the morphology of fusiform cambial cells, something more than the mere basipetal transport of auxin through the cambium is necessary for activation of cambial growth. It is well known that substances such as sucrose and phosphate ion are attracted to sites of high auxin concentration, and it could be that the concentration of these or other auxin-attracted factors are what are actually initiating cambial growth (Little and Savidge 1987).

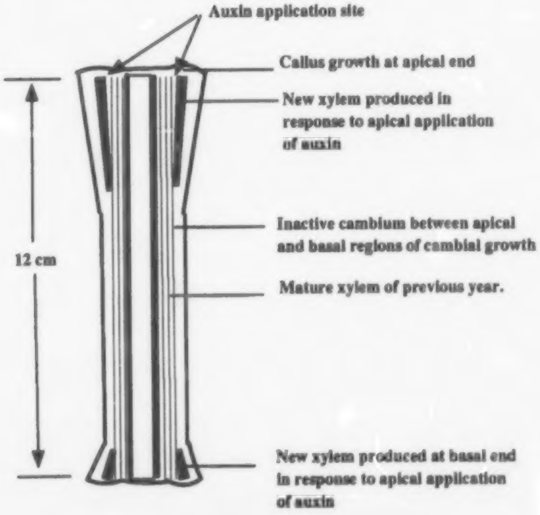

Auxin application site
Callus growth at apical end
New xylem produced in response to apical application of auxin
Inactive cambium between apical and basal regions of cambial growth
12 cm
Mature xylem of previous year.
New xylem produced at basal end in response to apical application of auxin

Fig. 5. Diagrammatic representation in median longitudinal section of the cambial response in a two-year-old disbudded-defoliated *Pinus contorta* cutting to apically applied auxin. Most cambial growth occurred immediately below the site of auxin application but some occurred at the basal end of the cutting. In the intervening region, through which auxin must have moved to reach the basal end, there was no evidence for cambial cell division activity. (After Savidge 1983).

When three- to ten-year-old overwintered quiescent conifers were debudded, but not defoliated, and given exogenous auxin in lanolin to their apical surfaces, cambial cell division activity and earlywood formation occurred in both the lower non-foliated portions of the main stem and the younger foliated portions. In 'control' trees, similarly debudded and given only lanolin to their apical surfaces, cambial cell division activity and earlywood formation also occurred but the distribution of cambial growth was different. The cambium beneath the site of lanolin application in the control trees de-differentiated into axial parenchyma and little or no earlywood developed in the younger foliated portions of the tree. But in the lower non-foliated main stem the cambium remained of normal morphology and produced an extensive layer of earlywood, greater in radial width than that occurring in non-treated trees having intact buds (Savidge and Wareing 1981b). Similar growth responses were observed in young disbudded conifer cuttings having intact leaves: exogenous auxin to the apical end was unnecesssary for the production of new xylem at the cutting base, but auxin to the apical end did influence the distribution of wood formation along the cutting axisin a manner similar to that shown in Fig. 5 for disbudded - defoliated cuttings. When naturally defoliated and disbudded older stem regions were investigated as 'cuttings' in the manner described, the sole anatomically detectable effect of exogenous auxin was the maintenance of the normal fusiform morphology of cambial cells. No evidence for tracheid differentiation in response to exogenous auxin applications was found in three-year-old or older defoliated main-stem conifer 'cuttings' (Savidge and Wareing 1981a, 1981b; Savidge 1983).

Savidge and Wareing (1981a, 1981b) and Savidge (1983) concluded that although auxin appears to have regulatory roles in maintaining the cambium and promoting radial expansion of primary-walled cambial derivatives, there must exist a factor from mature conifer needles which is essential for initiation of tracheid differentiation and which controls the extent of secondary-wall formation occurring in differentiating tracheids. This tracheid differentiation factor (TDF) was concluded to be distinct from IAA for several reasons: 1) IAA was found to promote cell division in the vascular cambium of young cuttings, whereas conifer leaves promoted tracheid differentiation in the absence of preceding cell division, 2) IAA stimulated radial enlargement of primary-walled cambial derivatives and conifer leaves did not, 3) conifer leaves stimulated tracheid differentiation of cells within the cambial zone *per se* as well as in centrifugally adjoining cambial derivatives that normally would differentiate into sieve cells, and IAA was never observed to have these effects, 4) conifer leaves stimulated tracheid differentiation both apical and basal to the junction of leaf traces with the stem vascular cambium whereas IAA induced activity only basal to the point of application, and 5) in three-year-old and older conifer 'cuttings' still having living needles, the presence of leaves promoted tracheid differentiation whereas exogenous auxin applied to apical ends of defoliated cuttings promoted neither cell division nor tracheid differentiation (Savidge and Wareing 1981a; Savidge 1983).

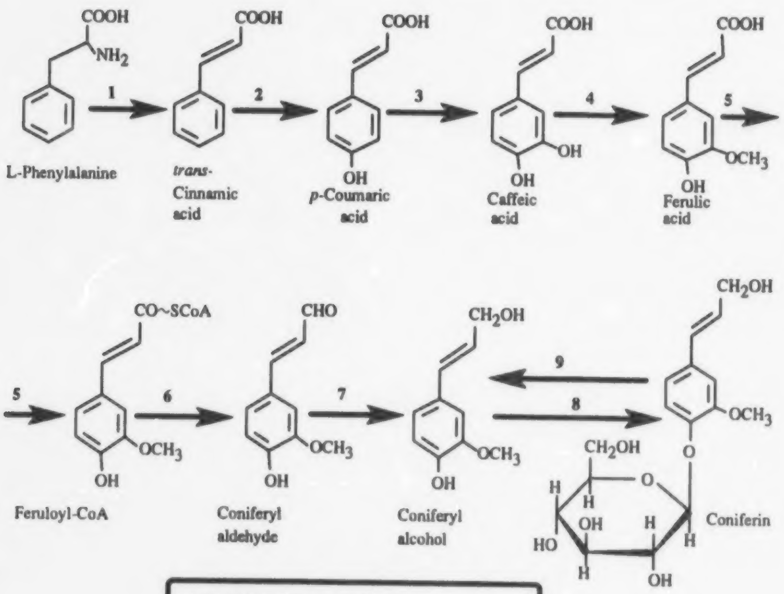
Additional evidence for the existence of TDF was sought and found (Savidge 1983, 1988a, 1989; Savidge and Wareing 1984). In sapling or larger conifers, cambial reactivation in spring characteristically resumes prior to budbreak, the first cambial cell division activity occurring in the region of the base of the living crown in the main stem. In contrast, the first earlywood xylem development characteristically begins in the foliated regions of the trees and from there migrates down the stem. The result is that shown in Fig. 4 (see also Savidge and Wareing 1981b, 1984). When samples were harvested at the beginning of the cambial growth period, numerous radially enlarged cambial derivatives, destined ultimately to become tracheids, were found as primary-walled cells in the lower regions of the stem. At a later date, when xylem development was well underway in the tree top, these radially enlarged primary-walled cambial derivatives at the crown base, although produced first, still remained to commence tracheid differentiation (i.e. bordered-pit development, secondary-wall formation and lignification). When peroxidase activity was stained for, a similar result was found (Fig. 4). Peroxidase activity became apparent first in the foliated regions of the tree top and appeared to progress basipetally from the crown toward the non-foliated regions (R. A. Savidge, unpublished data).

From the auxin and developmental findings reviewed above,it can be reasoned that endogenous auxin must be sufficiently present in stems of conifers to maintain the vascular cambium's fusiform cell morphology, to promote cambial cell division, and to promote radial expansion of cambial derivatives. But since there is a protracted lag in the region below the crown base between the time of production of radially enlarged cambial derivatives and later initiation of anatomically detectable tracheid differentiation or histochemically discernible peroxidase activity, it logically follows that biochemical factors which regulate occurrence of cambial cell division and radial expansion of cambial derivatives are not sufficient for occurrence of tracheid differentiation, that something (TDF) is wanting and that TDF apparently has its origin in the live crown.

In view of the well established relations between foliage biomass and stem dimensions, the possibility that TDF may be photosynthate, i.e. sucrose, was repeatedly tested both *in vivo* and *in vitro* with the conifer cambium; however, no evidence for promotion of tracheid differentiation by any concentration of sucrose, either with or without auxin, was ever found (Savidge and Wareing 1981a, 1981b; Savidge 1983, 1989, and unpublished data).

CYTOKININS

A considerable body of evidence now supports the theory that xylogenesis *in vitro*, whether in angiosperms or gymnosperms, requires a combination of auxin and cytokinin (Savidge 1989, 1990b). An auxin-cytokinin combination is well established to be necessary to induce lignification enzymes, notably phenylalanine ammonia lyase (PAL) but also other enzymes in the pathway (Fig. 6). Coniferin, an established storage reserve precursor of lignin, became detectable in the cambial region in spring time before resumption of cambial cell division activity, and coniferin accumulated in radially expanded cambial derivatives even before these commenced tracheid differentiation (Savidge 1988a, 1989). Coniferin biosynthesis requires the activity of PAL and additional enzymes shown in Fig. 6. It follows that cytokinin, like auxin, must be available to the cambium at the beginning of the growth season, and that an auxin - cytokinin combination, while sufficient for coniferin accumulation in the cambial region, cannot be sufficient for initiation of tracheid differentiation. This deduction is further supported by experiments with conifer cuttings. Extensive testing of exogenous cytokinins repeatedly confirmed that they, alone or in combination with auxin, did not promote cambial growth (Savidge and Wareing 1981a, 1981b; Savidge 1983, 1989). On the other hand, when the cambium was grown *in vitro*, it was found that cytokinins inhibited cambial growth as promoted by auxin (Savidge 1983, 1989).


COOH
NH2
L-Phenylalanine
1
COOH
trans-Cinnamic acid
2
COOH
OH
p-Coumaric acid
3
COOH
OH
OH
Caffeic acid
4
COOH
OCH3
OH
Ferulic acid
5
5
CO~SCoA
OCH3
OH
Feruloyl-CoA
6
CHO
OCH3
OH
Coniferyl aldehyde
7
CH2OH
OCH3
OH
Coniferyl alcohol
9
8
CH2OH
OCH3
O
CH2OH
O
H
H
OH
H
HO
H
H
OH
Coniferin

1=phenylalanine ammonia lyase
2=cinnamate-4-hydroxylase
3=*p*-coumarate-3-hydroxylase
4=*O*-methyltransferase
5=ferulate:CoA ligase
6=cinnamoyl-CoA reductase
7=cinnamyl alcohol dehydrogenase
8=uridine diphosphoglucose:cinnamyl alcohol glucosyltransferase
9=glucocinnamyl alcohol β-glucosidase

Fig. 6. The guaiacyl lignin pathway from phenylalanine to coniferyl alcohol and coniferin. Numbers correspond to enzymes shown in the box. (After Savidge 1989)

GIBBERELLINS AND ETHYLENE

In addition to auxin, ABA, and cytokinins, gibberellins and ethylene have established roles in regulating plant growth and development. Gibberellic acid (GA3), when applied exogenously, is synergistic with auxin in promoting cambial cell division activity and wood formation in hardwoods; GA3 by itself is conducive to differentiation of xylem parenchyma and is inhibitory to differentiation of prosenchyma (Savidge and Waring 1981b; Savidge 1990b). But in conifers exogenous GA3 by itself or with auxin has not been found effective in promoting radial growth (Little and Savidge 1987). Moreover, GA3 was found to inhibit tracheid differentiation (Savidge 1983). Common gibberellins occurring in conifers include GA1, GA3, GA4, GA7 and GA9 (R. P. Pharis, personal communication). Dihydroconiferyl alcohol, a gibberellin synergist, has also been identified in developing xylem (Savidge 1987). It is well established that foliar sprays of exogenous gibberellins control biomass partitioning between root and shoot systems (Little and Savidge 1987) and it therefore seems likely that gibberellins will be found to be at least indirect regulators of wood formation in conifers.

Ethylene has been found to be produced by cambia of hardwoods and many conifers, and also by vascular rays (Savidge 1988b). Known effects of ethylene on higher plants include promotion of very elevated respiratory levels in association with growth, inhibition of cell elongation and promotion of radial expansion, promotion of bond breakage between adjoining cells, and control of cytoskeletal microtubule and cellulose microfibril orientations. Ethylene, not very soluble in cell sap, tends to be released into the atmosphere within and about the plant wherever it is biosynthesized; thus ethylene lacks the hormonal trait of directed transmissibility. On the other hand, the water soluble immediate precursor of ethylene, 1-aminocyclopropane-1-carboxylic acid (ACC), does have the trait of transmissibility, and is well established to move in the transpiration stream. ACC has been positively identified in the cambium of one conifer, where it occurred abundantly in association with compression wood formation and was not detectable in the cambial region of the opposite wood (Savidge *et al.* 1983).

In two-year-old or younger disbudded and defoliated stem cuttings of conifers that were treated with exogenous auxin to their apical ends, considerable ethylene emanation was found (Savidge 1988a). But in three-year-old or older stem cuttings lacking buds and foliage, the ethylene emanation rate was significantly lower. The explanation for this difference appears to reside in the finding that three-year-old or older cambia, but not younger cambia, required exogenous ACC as well as auxin in order to produce ethylene (Savidge 1988). These findings are of interest for at least two reasons. Firstly, current thinking is that auxin promotes ACC but not ethylene biosynthesis; however my results suggest ACC can be limiting for cambial production of ethylene despite the presence of auxin. Secondly, the inability of three year old or older cambia to produce ethylene in the absence of either auxin or ACC may relate to the inability of these ages of cambia to respond to exogenous auxin, as reviewed above, in terms of either cambial cell division activity or wood formation.

CONCLUSIONS

Auxin and cytokinin have roles in regulating xylem development in conifers, whereas abscisic acid, ethylene and gibberellins remain more equivocal. Neither auxin nor cytokinin, alone or in combination, appears to be the factor initiating tracheid differentiation in conifers. There clearly is at least one as yet unidentified regulatory factor derived from conifer leaves that is essential for xylem development and derived from conifer leaves remaining to be identified.

ACKNOWLEDGEMENTS

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MANAGING FORESTS FOR MAXIMUM PRODUCT VALUE

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FDC: 815: 238: 651: 174.7 *Pseudotsugo menziesii* Franco

SUMMARY

Wood from a rapidly-grown managed forest resource will have different characteristics than that from unmanaged or old-growth forests. Industry may have to change the ways in which the new resource is converted, graded or marketed. In addition, forest managers should consider how their management strategies affect the value of the resource. An approach to this type of evaluation is illustrated by a study of Douglas-fir in coastal British Columbia.

Keywords: Managed forest, resource evaluation, end-product value, wood characteristics, Douglas fir.

INTRODUCTION

A large part of Canada's economy has developed around the utilization of our abundant, high quality softwood resource. The economically accessible part of this resource is, however, declining and the Science Council of Canada has suggested that if the present level of harvest is to be maintained, growth rates must be accelerated.

It is frequently assumed that the larger volume of wood produced through the application of intensive forest management practices will result in proportionately greater value. For the most part, this is not the case. When forests are managed for better growth rates, a change also occurs in the relative importance of factors, other than volume, which contributes to value. Wood properties, stem size and form, silvicultural costs, harvesting, transportation, processing and marketing costs as well as consumer preference and demand for products all effect value, and are either directly or indirectly influenced by forest management decisions.

It is understandable if the forest manager is confused by the complex array of wood and stem characteristics to be considered. Which ones have the greatest influence on product quality and for which products? A characteristic important to the quality of a solid wood product may not be important for a paper product. One approach is to consider the characteristics of logs and end-products that produce maximum value in today's marketplace. This is a rational approach but what about the uncertainty managers may feel when contemplating the products to be produced at the end of the next rotation period? Will industry still be sawing dimension lumber or will laminated veneer lumber or reconstituted strand products be the structural products of the future?

Faced with this complex problem, forest managers may decide to ignore wood quality considerations and simply attempt to increase wood volume productivity. To do so is to assume that somehow industry will be able to convert any quality of material into usable products. Technology can contribute a great deal to the problems of processing wood of lower quality to produce a desirable product, but this is usually achieved through increased energy usage, reduced yield, increased cost or loss of quality of final products. In order to maintain, or even improve our competitive advantage in the world marketplace, I believe we must not dismiss the question of future basic resource quality too quickly.

But what can we tell forest planners about the selection of important wood quality characteristics when we are unsure of what the nature of the future products will be? First let me comment on species selection. What is needed from the utilization viewpoint before a management plan is developed is a realistic assessment of the ability to provide a log volume sufficient to at least provide the potential for commercial success. If a site, disease or insect problem suggests that an alternate species should be planted be sure that the extent of planting is sufficient to develop and maintain a market for the products which can best be produced from the species.

Secondly, develop growing stock from fast growing provenances which exhibit good stem straightness, minimal stem taper and a uniform distribution of stem diameters. Select your growing stock from trees which put an absolute maximum of their available energy into the production of stemwood. This will maximize merchantable volume production and hopefully ensure that branch size and therefore knot size is minimal. Compact vigorous crowns will benefit both volume production and wood quality. In plantation forestry, we do not want trees that will divert available growth potential into heavy cone crops.

At some point, we must become quite specific and determine if there will be a wood quality problem for a particular species, and if so, develop a strategy for dealing with it. I believe the best way to approach this is through large, integrated, cooperative research projects which examine not only the basic wood properties of the fast-grown resource but also the product quality of this material as it s processed for pulp, lumber and composite products. This can be done in such a way that any problems can be related back to the particular basic wood properties responsible. An example of this approach is the recently completed program of research into managed second-growth coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) timber values undertaken by Forintek Canada Corp. in cooperation with the Pulp and Paper Research Institute of Canada and the Research Branch, B.C. Ministry of Forests. This research group called the Douglas-fir Task Force had the following main objectives:

1. To estimate the physical, mechanical and chemical properties of the intensively managed coastal Douglas-fir resource of the future.

2. To determine the value of this resource for conversion to dimension lumber and pulp.

3. To develop a computer model capable of evaluating the effects of silvicultural treatments in terms of end-product value.

EXPERIMENTAL METHODS

Formation of the Douglas-Fir Task Force

Securing the active support and participation of industry was an absolute necessity in order to ensure the success of the task force. Six of the coastal companies, B.C. Forest Products, Crown Forest Industries (now both under the name Fletcher Challenge), Canadian Forest Products, MacMillan Bloedel, Western Forest Products and C.I.P. Inc. (now called Canadian Pacific Forest Products) all offered to locate suitable stands, fell trees and transport logs to the mill. Canadian Pacific Forest Products made their Ladysmith mill available for the conversion study. Representatives from each company and the Ladysmith mill manager joined the nine project leaders to form the Douglas-fir Task Force.

Site and Tree Selection

Six stands were sampled. The age of these stands was approximately that of the anticipated rotation age of future managed stands of Douglas-fir, that is, about 50 years. Intensively managed stands of that age do not exist in coastal British Columbia, but 50 year old stands do exist on medium to good sites where stocking densities are not too high and productivity has been at levels that foresters would hope to achieve under intensive forest management conditions. It was this type of stand which was sought for study. In addition, it was decided to obtain as wide a geographic distribution of sites as practical and to represent both the wet and dry regions on the West and East coasts of Vancouver Island as well. The flow of trees, logs, and material selected for each of the study projects is illustrated in Figure 1.

It must be kept in mind that the material sampled, and therefore the results, do not describe the present coastal Douglas-fir resource being harvested and marketed today. The results of the basic wood property, pulping, and juvenile-mature wood transition studies do not truly describe the entire stands from which they were obtained since only dominant and codominant trees were selected. It is expected that the trees selected for study represent the range of characteristics which will be produced in future managed stands of this species.

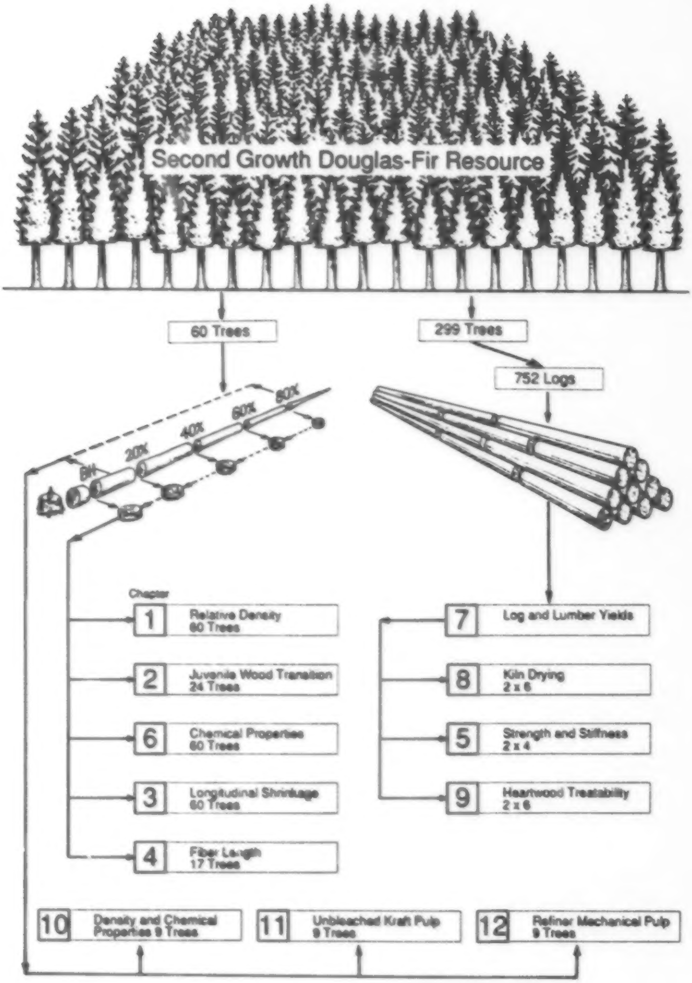
Second Growth Douglas-Fir Resource
60 Trees
299 Trees
752 Logs
BH
20%
40%
60%
80%
Chapter
1 Relative Density 60 Trees
2 Juvenile Wood Transition 24 Trees
6 Chemical Properties 60 Trees
3 Longitudinal Shrinkage 60 Trees
4 Fiber Length 17 Trees
7 Log and Lumber Yields
8 Kiln Drying 2 x 6
5 Strength and Stiffness 2 x 4
9 Heartwood Treatability 2 x 6
10 Density and Chemical Properties 9 Trees
11 Unbleached Kraft Pulp 9 Trees
12 Refiner Mechanical Pulp 9 Trees

Fig. 1 Source and distribution of trees and material in study projects

Sampling of the stands for the conversion study was more comprehensive in that the full range of tree diameters was sampled. The sampling plan called for an equal number of trees in each diameter class so that estimates would have equal precision over the full range of stem diameters. However, the results do not properly describe these stands since the sampling was not random. That was not the objective of the study.

RESULTS AND DISCUSSION

Wood Characteristics

The results of this study show that, largely due to the high proportion of juvenile wood, second-growth coastal Douglas-fir harvested in 50 to 70 years will have physical, mechanical and chemical properties substantially different from the old-growth resource harvested today. Juvenile wood volume may be as high as 50 percent of total volume at these rotation ages. Juvenile wood, which in this study material comprised on average the first 23 rings from the pith, has an average relative density of 0.46. The average stemwood relative density of the study trees is 0.48 while the best estimate of average old-growth relative density is about 0.51 to 0.52.

A great deal of tree-to-tree variation in longitudinal shrinkage exists, but on average the longitudinal shrinkage of the innermost juvenile wood is more that twice that of mature wood. No sharp distinction can be observed between juvenile and mature wood based on longitudinal shrinkage, but it appears that the most serious levels are generally confined within the first five rings from the pith. In contrast, the fiber length increased dramatically from between 1.0 and 2.0 millimeters at the pith to between 3.0 and 4.0 millimeters in the mature wood. These mature wood values were not attained for approximately 30 rings from the pith, so it can be anticipated that the average fiber length of short rotations stands will be substantially less than that of old-growth material.

In terms of chemical properties, lignin content of juvenile wood is higher than that of mature wood, but a comparison of the mean second-growth values with those available for old-growth shows that they are not appreciably different. A similar comparison shows total extractive content of second-growth is lower than that of old-growth.

Conversion to Dimension Lumber

The factor primarily determining lumber value is tree and log size. Grade No. 2 and Better accounted for a relatively constant average of 82 percent of all lumber. Increased yields of Select Structural that were obtained as log diameter increased were largely at the expense of reductions in the yield of No. 1 and No. 2 lumber. Clearly, differences in lumber value related to log quality depend on a premium price for Select Structural. Without this premium for grade the effect that logs size has on value would become even more important, because premium prices are usually paid for the widest lumber widths.

RESULTS OF EUCALYPTUS X TRABUTII FOUR-YEAR CLONAL TESTS IN ITALY

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FDC: 165.62: 181.51: 232.13: 176.1 Eucalyptus x trabutii

Eucalyptus x trabutii, identified for the first time in North Africa by Vilmorin, is a natural hybrid between E. camaldulensis and E. botryoides. This species has been widely and successfully used in South Italy in productive and/or protective plantations over the last 20 years.

To reduce segregation, which is typical of the progeny coming from hybrid parents, and to improve planting stock, some clones were selected for their ability to root from herbaceous cuttings.

In spring 1986 two clonal tests, with 13 and 18 clones respectively, were established in two different Sardinian sites. A randomized block design was used, with seven replications and a 16-tree plot.

The work reports the results concerning four-year tree growth (BHD and height) in the two trials.

A CONCEPTION FOR DEVELOPMENT OF FIRE-RETARDANT WOOD MATERIALS

-FROM RESEARCH ON THERMAL ANALYSIS OF WOOD TREATED WITH WATER-INSOLUBLE RETARDANTS-

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SUMMARY

Combustion of wood and methods for fire-retardant wood are briefly reviewed first, and then a study on TG and DTG of five water-insoluble retardants and wood treated with the retardants are presented. The results of TG and DTG are discussed in kinetic manners, and models of fire-retardant materials are proposed for interior and exterior use from the review and the results of the thermal analyses.

Keywords: Fire-retardant, pyrolysis, TG, DTG, activation energy

INTRODUCTION

Various kinds of flame-retardants have been used for synthetic polymer materials. The greater part of these retardants has not been applied in the case of wood, probably due to their insolubility in water or difficulty in the treatment of wood. To pioneer a way to utlilize the insoluble retardants, plywood glued by resin containing them has been tested (Saito et al. 1987). Application of retardants mixed with glues seems to be a likely procedure in order to restrain increase in production costs of fire-retardant wood materials such as plywood and particleboard. Effects of the insoluble retardants on pyrolysis of wood, however, have rarely been reported. This paper describes thermogravimetry (TG) and derivative thermogravimetry (DTG) of wood treated with several retardants insoluble in water which are applicable to wood materials in mixing with resin glue, and proposes models for development of fire-retardant wood materials from the results.

BACKGROUND

Flaming Combustion of Wood

Wood starts flaming combustion after two conditions have been satisfied. One is the formation of an appropriate flammable gas-air concentration around the wood, determined by the pyrolysis rate of wood and the diffusion of the pyrolysis gases. The other is the elevation of the surface temperature up to around 500 °C (Akita 1959), otherwise igniters such as electric sparks and a pilot flame have to be given. In the case of heating by radiation the surface temperature condition would be established first, while in the case of convection it would be established last.

The TG curves of wood components shown in Fig. 1 indicate that cellulose, which amounts to about 50 % weight of wood, rapidly generates volatiles in the temperature range from 310 to 380 °C and leaves a small amount of charred residue and that lignin and hemicellulose lose weight more slowly and leave much greater amounts of char. Therefore, the cellulose component of wood causes and feeds flaming combustion, because its high pyrolysis rate overcomes the diffusion rate of produced volatiles and makes them concentrated. In other words, cellulose is probably exclusively responsible for the first condition above. The latter surface temperature condition depends on the heat capacity and thermal conductivity in addition to external factors such as heat sources. Otani (1989) has estimated that the surface temperature rise is slower with increasing the density of wood because of increased heat capacity and thermal conductivity.

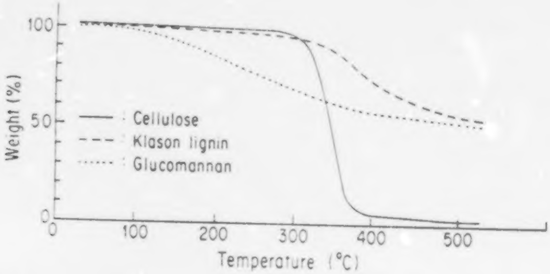

Fig. 1: TG curves of wood components *in vacuo*, constructed by modifying results by Ramiah (1970). Heating rate: 4 °C/min.

Ways to Achieve Fire-Retardant Wood

The various methods to achieve fire-retardant wood which have been presented may be divided into three categories of chemical effects on pyrolysis reactions, inhibitory effects in the gas phase, and thermal effects. The methods in the first category aim to modify the pyrolysis course toward production of nonflammable volatiles, thus slowing down the pyrolysis rate, and/or thermally stabilizing wood chemical structures with cross-linking or grafting. One of ideal modifications is dehydration and carbonization, and is expressed below:

$$(C_6O_5H_{10})_n \text{ (Wood)} \longrightarrow 6nC \text{ (Char)} + 5nH_2O \qquad (1)$$

The second kind of methods inhibits combustion of flammable volatiles by generating halogen radicals which compete with O_2 for reactions with H and OH radicals in chain branching reactions of flaming combustion, by evolving non-flammable gases to dilute flammable gases, or preventing contact between O_2 and flammable gases by physical barriers such as coatings.

The third type restrains the temperature rise by forming insulation on the surface such as coating and charred layers, by chemically or physically absorbing heat, for instance, by vaporizing crystal water of retardants and increasing heat capacity, or by dissipating heat faster than supplied by the heat source by increasing the thermal conductivity. Effects of the heat capacity, the thermal conductivity, and the heat of vaporization or reaction on the temperature rise in the x direction within wood may basically be understood from a simplified equation

$$dT/dt = \kappa/(\rho c)\cdot d^2T/dx^2 + \Delta H/(cw)\cdot dw/dt \qquad (2)$$

where T is the temperature, t the time, κ the thermal conductivity, ρ the density, c the specific heat, ΔH the heat of vaporization or reaction, and w the normalized weight. Furthermore, the temperature dependence of the overall pyrolysis rate of cellulose may be expressed as

$$-dw/dt = A\exp(-E/(RT))\cdot w^n \qquad (3)$$

where A is the pre-exponential factor, E the activation energy, R the gas constant, and n the order of reaction. A recently developed semi-noncombustible wood, "Ceramic Wood" (Nishimoto et al. 1987) seems to be given its performance by increasing the heat capacity and thermal conductivity. These increases restrain the temperature rise of the outer layer, and then the pyrolysis, as seen from Eqs. (2) and (3).

Temperature Characteristics

and Evaluation of Performance

Temperature within wood during heating is a function of the time and the distance, as stated above. The temperature changes may schematically be shown by temperature profiles assumed for this purpose in Fig. 2, which seem to agree with Akit (1959) and Otani (1989). The main pyrolysis of wood would start at temperatures above 250 °C and finish below 400 °C. However, the char surface could have temperatures above 800 °C, as estimated from charcoal combustion. Therefore, in order to modify the pyrolysis course retardants must work at temperatures below 250 °C. It is also desirable for inhibitory effects in the gas phase that retardants or coatings work over a wide temperature range from 250 to 800 °C. A great effect in the above third category would be obtained by keeping the temperature under 310 °C, which cellulose begins to rapidly pyrolyze at.

Fire-retardant performance of wood materials is evaluated from several aspects, namely, ignitability, flame spread, smoke generation, and combustion gas toxicity. Retardants yielding inhibitory effects might improve the ignitability and the flame spread, but might increase the generation of smoke and toxicants. Retardants to modify the pyrolysis course might not give great effects on the first two properties but might much improve the smoke generation and the toxicity. Although it would not be easy for treatment for thermal effects to get high efficacy, they seem likely to clear all four barriers in the future. Furthermore, according to purpose of use, fire-retardant materials have to be evaluated regarding other properties such as mechanical strength, bond strength, hygroscopicity, weathering resistance, and so forth.

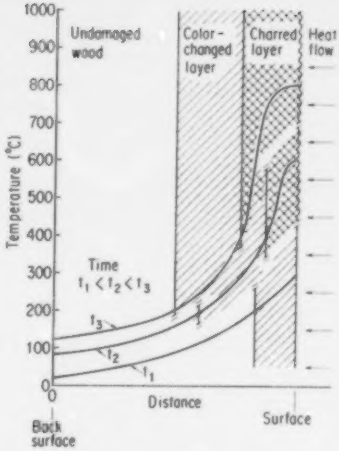

Fig. 2: Schematic temperature profiles in wood heated.

EXPERIMENTAL

Red meranti wood (*Shorea* spp., *red meranti* section) was pulverized into particles of 0.4-0.8 mm diameters. The retardants used were poly(ammonium phosphate) $HO(-NH_4PO_3-)OH$ (named PAP here) whose degree of polymerization was 50 to 100, melamine phosphate $H_3PO_4 \cdot C_3N_3(NH_2)_3$ (named MP), trischloroethyl phosphate $(C_2H_4Cl)_3PO_4$ (TCEP), tetrabromobisphenol A $HOC_6Br_4-C(CH_3)_2-C_6Br_4OH$ (TBA), and decabromodiphenyl oxide $C_6Br_5-O-C_6Br_5$ (DBDO). The dried wood was first mixed in water with PAP, MP, or DBDO, or immersed in an ethanol solution of TCEP or TBA. The water was removed by freeze-drying after the mixtures were filtered through fused glass. The methanol was removed by means of a rotary evaporator. The amounts of retardants taken up were determined from the differences in sample weights before and after the treatments.

TG and DTG were carried out in an atmosphere of air or helium flowing at the rate of 80 mL/min using a Sinku Riko DTG-5000 Differential Micro Thermal Balance. The initial weights of the wood samples and the retardants were 9-10 and 4-5 mg, respectively.

RESULTS

Retardants

The threshold temperature of weight losses in TG in helium was the

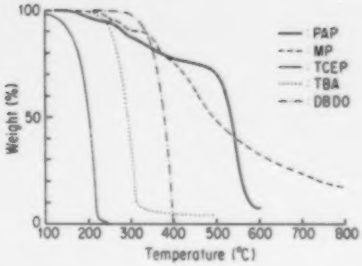

Fig. 3: TG curves of retardants in helium. Heating rate: 5°C/min.

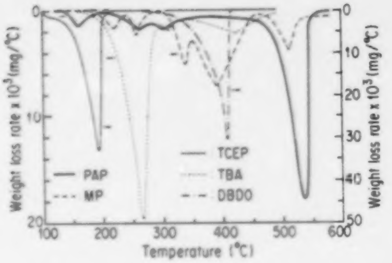

Fig. 4: DTG curves of retardants in air. Heating rate: 0.5 °C/min.

lowest for TCEP, the second lowest for PAP, and then for TBA, and the highest for DBDO and the second highest for MP, as shown in Fig. 3. The most rapid and main weight loss occurred earliest for TCEP, followed by TBA, and then DBDO, and latest for PAP and the later for MP. Similar TG curves were obtained in air, but all of the weight losses occurred at higher temperatures than in helium and the beginning temperature of the weight losses was a little lower for MP than for TBA. The weight losses of PAP and MP in the both atmospheres consisted of four and five steps, respectively, as shown by peaks in the DTG curves in Fig. 4. The pyrolyses of these two retardants seem to progress by undergoing decomposition and condensation in turn, which produce H_2O, NH_3, and so forth into the atmosphere and active fragments in the solid state to end up with formation of a residue of macromolecules. TBA in air showed a weight loss of three steps.

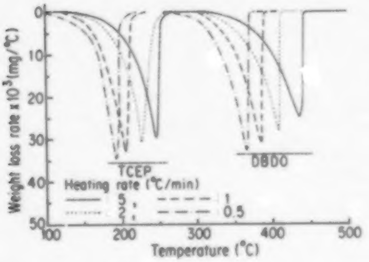

Fig. 5: DTG peaks of TCEP and DBDO in air.

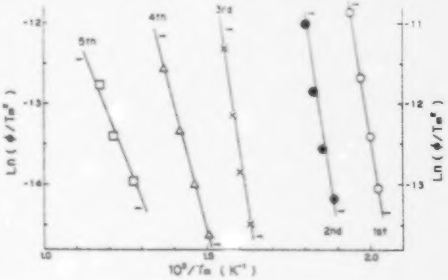

Fig. 6: Plots of the reciprocals of the DTG peak temperatures vs. $\mathrm{Ln}(\phi/T_m{}^2)$ for MP in air.

The DTG peak temperature rises with increasing heat rate, as shown in Fig. 5. Akita and Kase (1967) have derived

$$\mathrm{Ln}(\phi/T_m{}^2) = \mathrm{Ln}\,((nRA/E)(W_m)^{n-1}) - E/(RT_m) \qquad (4)$$

from Eq. (3), where φ is the heating rate and m denotes the state of maximum weight loss rate. We can get the activation energy by plotting the left-hand side against $1/T_m$ in Eq. (4). The plots according to Eq. (4) gave straight lines, as shown by examples for MP in Fig. 6, and the obtained activation energies are listed in Table 1.

Table 1: Activation energies for pyrolyses of retardants

Samples	Atmosphers	Activation energies (kJ/mole)				
		1st	2nd	3rd	4th	5th
PAP	Helium	112	105	142	191	
	Air	148	125	103	198	
MP	Helium	198	211	174	83	208
	Air	219	219	224	128	84
TCEP	Helium	91				
	Air	74				
TBA	Helium	106				
	Air	90	203	150		
DBDO	Helium	120				
	Air	111				

Wood Samples

In helium all the retardants except MP accelerated the beginning of weight loss of samples in TG. MP had little effect on the weight loss, as shown in Fig. 7 (MP in the smallest content of 4.8 % a little delayed the overall weight loss). The char yield from the PAP treated wood is the largest and the others did not much differ from that from the untreated sample. Each DTG curve shows two peaks including shoulders except for samples containing

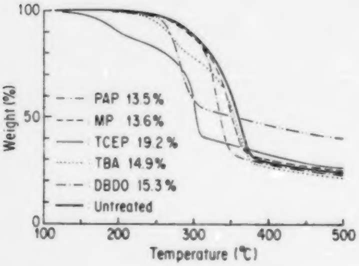

Fig. 7: TG curves of wood treated with retardants in helium. 5 °C/min.

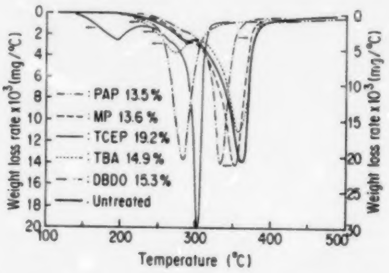

Fig. 8: DTG curves of wood treated with retardants in helium. 5 °C/min.

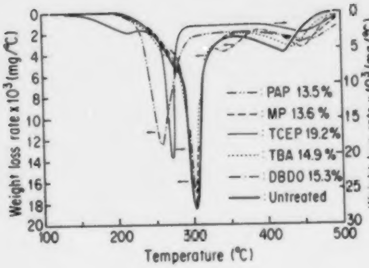

Fig. 9: DTG curves of wood treated wood with retardants in air. Heating rate: 5 °C/min.

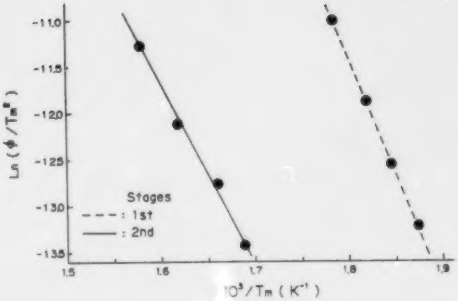

Fig. 10: Plots of $1/T_m$ for first and second step weight losses vs. $Ln(\phi/T_m^2)$ for untreated wood in helium.

13.5 and 23.3 % PAP, and 20.2 % DBDO, as shown by examples in Fig. 8. For the untreated sample the first small peak may be caused by the pyrolysis of some weaker components, probably some hemicellulose, and those for the treated samples may be due to the acceleration of pyrolysis of the weaker components by retardants. The main peaks probably come from cellulose.

In air the weight losses occurred at lower temperatures than in helium. They also began sooner in the cases of TCEP and PAP, but the other retardants had little effect on the weight loss behavior except that the char yields were larger for the treated samples than for the untreated ones. All the samples showed two DTG peaks, as shown in Fig. 9. Those at low and high temperatures may be due to pyrolysis of cellulose and char oxidation. Furthermore, the TCEP and TBA treated samples showed small peaks at lower temperatures which are ascribable to some weaker components.

Linear plots according to Eq. (4), as shown by examples in Fig. 11, enabled us to obtain activation energies for the weight losses represented by the DTG peaks. The activation energy, 214 kJ/mole for the first peak of the untreated wood in helium was reduced by retardants to a range from 75 kJ/mole for the TCEP treated wood to 206 kJ/mole for the samples containing 13.6 and 4.8 % MP. Those for the main weight losses are shown in Fig. 11. It seems that TCEP and TBA had little effect on the activation energy while DBDO and MP increased it as their content increased, though MP reduced it as its content increased from 0 to 4.8 %. For the PAP treated sample, the highest activation energy was given for medium content in the studied range. In air, the activation energy for the DTG peaks at the lowest temperature ranges from 79 kJ/mole for the sample having 25.4 % TCEP to 214 kJ/mole for the sample having 32.2 % TBA content. The activation energy for the main weight loss of the PAP treated sample shows a similar change with the content to that in helium, as shown in Fig. 12. That for the TCEP treated sample is almost constant irrespective of the content, but the values are higher than for the untreated sample. DBDO had little effect on the activation energy. For TBA and MP, although the first increase in the content from 0 % caused some reduction, further increases caused increases in the activation energies. The

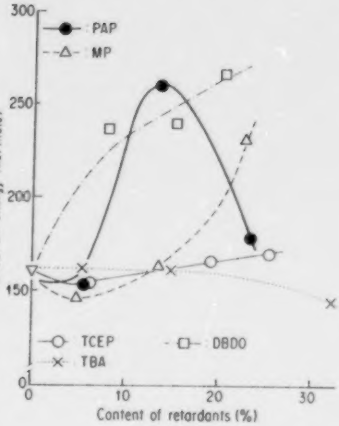

Fig. 11: Activation energies for the main weight loss of retardant-treated wood in helium.

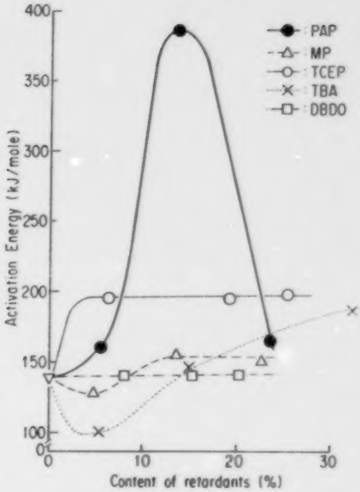

Fig. 12: Activation energies for the main weight loss of retardant-treated wood in air.

activation energy for the char oxidation also changed with the retardant contents, as shown in Fig. 13.

DISCUSSION

In all cases except for MP, the lower the temperature of main weight losses of the retardants (the fourth step for PAP), the lower the activation energy became, as shown in Table 1. Therefore, the obtained activation energies generally seem to indicate their thermal stability. Although the weight losses occurred at lower temperatures in helium than in air, the activation energies for TCEP, TBA, and DBDO are lower in air than in helium. Oxygen in air may delay the initiation of weight loss through some mechanism, however, oxygen may accelerate the weight loss, once it commences.

In both the helium and air atmospheres, the main DTG peaks for wood samples are ascribable to pyrolysis of cellulose. In a stationary state the weight loss of cellulose through pyrolysis may be expressed as

$$-dw/dt = k_i k_{dp}/k_t \cdot w^n \tag{5}$$

where k is the rate constant, the subscripts i, dp, and t denote the reactions of initiation of random chain scission, depropagation to split off flammable levoglucosan as a monomer, and grafting termination between a hydroxyl group and an activated center, respectively (Hirata 1979). Although various values of n have empirically been obtained, they are for the most 1 or 0. Also n could theoretically take different numbers depending on the packing density during the pyrolysis (Hirata and Werner 1987). From Eq. (5) it is seen that the obtained activation energies of weight loss for the above three reactions can be expressed as

$$E_w = E_i + E_{dp} - E_t \tag{6}$$

where the subscript w denotes the weight loss. The initiation reaction accelerated by an agent would cause a decrease in E_w as well as in the threshold temperature of weight loss. Also acceleration of the depropagation would lower E_w. Acceleration of the termination, however, increase E_w and thermally stable network structures.

In helium small amounts of PAP and MP seem to accelerate the initiation and/or the depropagation a little, and then to reduce E_w, as shown in Fig. 11. PAP may also accelerate dehydration, as inferred from ammonium phosphate. An increase in the PAP content from 5.6 to 13.5 % would mainly cause the acceleration of dehydration to form cross-linked structures and then to increase E_w, but further increase may accelerate decomposition of the cross-linked structures to reduce E_w, because of the limited number of hydroxyl groups available to the cross-linking. The increase in E_w with increasing DBDO and and MP may be due to accelerated termination. TCEP and TBA may substantially have disappeared before cellulose begins pyrolysis. Therefore, the effects of them on E_w are small.

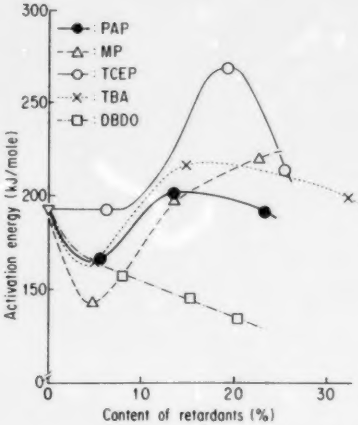

Fig. 13: Activation energies for oxidation of char.

The air atmosphere accelerates the pyrolysis of cellulose but delays the beginning of pyrolysis of the retardants. DBDO in air was probably too stable in the pyrolysis temperature range of cellulose to affect E_w. The change in E_w for the PAP treated wood in Fig. 12 may be explained in the same manner in helium. The increase in E_w by TCEP may be due to accelerated termination. Since TCEP acts only at the initial stage of the pyrolysis when groups reactive to the termination, probably in the amorphous region are limited in the number, almost constant E_w was given irrespective of the content. In air TBA became active at the pyrolysis temperature of cellulose. TBA and MP seem to accelerate the initiation and/or the depropagation more than the termination in low amounts while accelerating the termination more for higher contents. These different effects depending on the contents may be related to the multiple steps of the pyrolysis of TBA and MP which were shown in the DTG curves in Fig. 4.

Activation energies for oxidation of the char from the TCEP treated samples, shown in Fig. 13, may indicate the char stability. The others, however, have to be explained as effects of retardants or products from the retardants on the oxidation.

PROSPECT FOR FIRE-RETARDANT MATERIALS - CONCLUSIONS

It is suggested that the retardants studied have three different actions on combustion of wood. The first one is the dehydration accompanying cross-linking by PAP, and the second one is the stabilization of cellulose structures through the termination by DBDO in helium, TBA in air, and MP. The third one is the inhibition of flaming combustion in the gas phase by TCEP, TBA, and DBDO, which mainly release volatile halogen products in temperature ranges of 150-200, 250-300, and 350-400 °C, respectively. (Ion chromatography which was carried out in the laboratory indicates evolution of halogen compounds from these retardants in TG.) PAP and MP mainly work below and above 250 °C, respectively.

By associating these with the temperature profiles in Fig. 2, it is recommended that TCEP should be contained in the inner part of wood materials, TBA should be distributed in the outer part, and DBDO should be included in the charred layer. It, however, must be noted that high contents of these three retardants may increase smoke generation and not improve the combustion toxicity, as analogized from an inhibitory effect of ammonium bromide on combustion of plywood (Hirata et al. 1989). PAP and MP may colloborate in the formation of a thick and stable charred layer by dehydrating the structures stabilized with MP, as suggested from synergistic effects of ammonium phosphate and boric acid which have similar effects to PAP and MP, respectively (Hirata et al. 1989).

In conclusion a model of fire-retardant wood material for interior use is proposed which contains both retardants to accelerate the dehydration and the stabilization of structures, such as PAP and ammonium phosphate (ammonium phosphate works at the almost same temperature range as for PAP, as seen by TG and DTG curves in Fig. 14), and MP and boric compounds in the outer layer, and contains retardants to evolve halides, such as ammonium bromide, TBA,

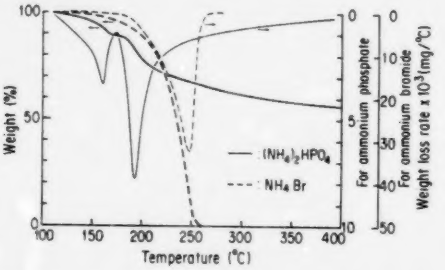

Fig. 14: TG and DTG curves of diammonium hydrogen phosphate and ammonium bromide in helium. Heating rate: 5 °C/min.

and TCEP, in the inner part. TCEP and ammonium bromide, however, have to be distributed in the innermost part due to the low pyrolysis temperatures, as shown in Figs. 3 and 14. At the early stage of heating, below a material temperature of 300 °C, the retardants for the dehydration and the stabilization would work well to form a charred layer, and in the later stage of higher temperatures greater than 300 °C the retardants for the inhibitory effect would restrain flaming combustion.

For the exterior materials water-soluble retardants should not be applied becasue of leaching out by rain. Generation of smoke and acute toxicants are not important problems in this case. A model is presented which contains PAP, and MP and/or DBDO which stabilize cellulose through lack of oxygen in the outer layer, and contains TBA, DBDO, and/or TCEP in the inner part. In order to distribute different retardants in different locations in the material, application is desirable for the cases of particleboard, fiberboard, plywood, and some composite materials.

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FIRE-RESISTANCE OF WOOD-POLYSTYRENE COMPOSITE IMPROVED WITH ORGANOPHOSPHATES

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SUMMARY

Investigations vere carried out on the combustibility of sapwood of scots pine (Pinus silvestris L.) and alder (Alnus glutinosa Gaertn.) impregnated with styrene containing trichlorethylphosphate (TCEP) and tridichlorpropylphosphate (TDCPP) in quantities 10 ÷ 30%. It was found that used organophosphates did not hinder polymerisation process of styrene and did not influence significantly its strength. In the tests of combustibility with gravimetric-ignition method it was found distinct decrease of the speed of combustion of wood-polystyrene composite in dependence upon of fire-retardant kind and its quantity in styrene. There was also observed favourable influence of TDCPP on selfextinguishing of burning material after removal of flame after 5 and 15 minutes of test time.

Keywords: wood-polystyrene composite, combustibility, fire-retardants, trichlorethylphosphate, tridichlorpropylphosphate

INTRODUCTION

The high requirements for structural materials and wood products are closely bound with the problem of its properties ameloration. Conducted from many years investigations are tending to eliminate of determined wood defects, with simultaneous presrvetion of its many adventages. This activities are favoured by dynamic development of chemistry of high-molecular compounds. One of examples could be trials to the wood improvement with the use of numerous syntetic-resins introduced into it, in the form of monomers or their mixtures and their polymerisation. The practical solution of this problem is technology of production of the so called "Lignomer", wchich is wood-styrene composite. Styrene polymerisation in wood, in "Lignomer" case is carried out by the thermal-catalytic method (Ławniczak 1979). The appearance of this new composite material was inspiration for series investigations on its properties and use possibilities

It can be generally stated, that wood-polystyrene composite is characterised in comparison with the wood with lower hydrophylity, decreased swelling, higher mechanical strength and also in determined range of increased biological durability properties (Lutomski 1975, Lutomski and Ławniczak 1972, Gambetta and Orlandi 1989).

Both composite components, that is wood and polystyrene, beeing undurable on the fire action are causing, that also "Lignomer" has easily combustible characteristics.

In the accessible for the author literature there were found information on the attempts to decrease combustibility of wood-polymer composite. Such investigations were carried out among others by Raff, Herrick and Adams (1966), Sciau, Meyer and Kulik (1972). It results from them that flame spreading speed on the burning material surface and intensity of exuding smokes is of great importance. The last phenomenon is to be considered in aspect of men hazard.

From the till to this time carried out work it is known that decrease of combustibility of wood-synthetic resins composites could be reached by the addition to them of fire-retardants. By such properties are characterised phosphorus compounds such as ammonia phosphates and organophosphates. The last mentioned are to be specially considered due to good solubility in monomers used in production of wood-polymere composites (Czechowski and Zakrzewski 1983, Grinberga, Krejtus and Zoldners 1989, Lübke and Jokel 1979, Sciau, Campos and Meyer 1975). Czechowski and Zakrzewski (1989) investigated thermal stability of wood-polysterne composite with addition of silans and found differences in the course of thermal wood and WPC decomposition.

The object of investigations on wood combustibility impregnated with other than styrene monomers were works of Nikolov and Panajotov (1979), Shutov, Petrov, Erdman and Vjazolin (1978), Panajotov (1988) and also just mentioned Sciau, Campos and Meyer (1975) and Sciau, Meyer and Kulik (1972). Ishikara (1988) obtained effect of lowering combustibility of particleboards glued with polymeric isocyanate adhesive with triethylphosphite addition.

EXPERIMENTAL METHODS

The scope of this paper are investigations on wood-polystyrene composite, containing additions organophosphates. The choice of proper chemical lowering combustibility of such composite has to be done with taking into consideration series conditions. There are to be mentioned material properties, its components, production technology etc. To the more essential demands in respect to combustion process inhibitors we may count solubility in monomers, lack of influence upon polymerisation reaction course, durability in application conditions, ability to act as factor retarding combustion.

Initial tests and actual possibilities of home industry allowed for qualification to more widely planned investigations following compounds:

- trichlorethylphosphate (TCEP),
- tridichlorpropylphosphate (TDCPP).

Used compounds are produced by Heavy Organic Synthesis Institute "Blachownia" in Kędzierzyn - Poland. Their general characteristics are presented in table 1.

Table 1

Some properties of trichlorethylphosphate (TCEP) and tridichlorpropylphosphate (TDCPP)

Property	TCEP	TDCPP
Acid number $(\frac{mg\ KOH}{g})$	0,59	0,60
Density at 25°C (kg/m^3)	1501	1411
Viscosity at 25°C (cP)	31,93	16,27
Phosphorus content (%)	10,5	7,2
Chlorine content (%)	36,5	49,0
Water content (%)	0.49	0,06

Following tests were made:

- determination of fire-retardandts influence on the styrene polymerisation reaction course and on pine and alder wood combustibility;
- determination of influence of fire retardandt addition to styrene on mechanical strength of wood-polymer composites;
- determination of combustibility of wood-polystyrene composite obtained with addition of various quantity of TCEP and TDCPP.

Influence of mentioned combustion inhibitors on the course of styrene polymerisation reaction was determined by definition of free styrene content in sample containing various quantities of TCEP and TDCPP and polymerised in temperature 95°C (Kuczyński 1974).

Determination of effect of provided for investigations organophosphates on the combustibility of pine and alder wood was made with the use of radiation method. The "Prüfstrahler" apparatus produced by "Pyro-Werk" (FRG) was used. The choice of this method was made mainly due to small dimmensions of samples (45x60x60mm) and preliminary character of this test. The samples were impregnated with the "full-cell process" method with acetone solutions of TCEP and TDCPP. For each plot 10 samples was prepared. The samples after impregnation were seasoned during 6 weeks in temperature 20°C and relative moisture content about 65%.

Determination of the influence of impregnation of wood with styrene to which various quantities of TCEP and TDCPP upon the wood strength was made on the samples 10x10x120mm, obtained from the squares of properly greater dimmensions, previously impregnated with styrene, polymerised then with the use of thermal-catalytic method. Samples 30 per one batch, were seasoned in temperature 20°C and relative moisture content 65% during 6 weeks, and after that their static bending strength was tested.

Samples of wood-polystyrene composite for the combustibility tests were obtained by the impregnation of pine wood (Pinus silvestris L.) and alder wood (Alnus glutinosa Gaertn.) with styrene monomer by the "full-cell process" method. This monomer contained proper additions of initiators and catalysts of polymerisation, which was conducted in liquid medium, in temperature up to 110°C, accordingly to the technology described by Ławniczak and Walentynowicz (1979). Before the starting up the wood impregnation, to the impregnation mixture 10, 20 and 30% of above mentioned fire-retardants was added. In the Table 2 polysterne content in samples was given and content of used organophosphates in tested material composites.

Table 2

Content of polystyrene and fire-retardants in wood and in the wood-polystrene composite (WPC)

Kind of wood	Content			
	of fire-retardant in styrene	of polystyrene in WPC	of fire-retardant	
			in relation to wood	in relation to WPC
	%			
Trichlorethylphosphate				
pine	-	121	-	-
	10	109	11,8	5,6
	20	88	23,0	10,8
	30	80	35,5	16,9
alder	-	110	-	-
	10	97	12,3	6,1
	20	87	25,4	10,1
	30	87	34,6	16,2
Tridichlorpropylphosphate				
pine	-	121	-	-
	10	110	13,1	5,9
	20	105	28,0	11,9
	30	85	36,6	16,7
alder	-	102	-	-
	10	101	10,2	4,9
	20	88	20,4	9,8
	30	81	33,4	15,4

Investigations of combustibility of wood-polystyrene composite was conducted with the use of gravimetric-ignition method. This metod is based on Schlyter indications (Lindner 1963), was described in details by Fojutowski and Urbanik (1976). This method enables measurements of combustuion speed process of board materials, determined by percentage losses of mass of tested materials in time, that enables also determination of sample inflammability, characterised by the time, after which takes place flame jump from the sample directly exposed on the fire action, on the sample oppositelly positioned. Besides that in the gravimetric-ignition method the time of independent burning of the tested material after flame removal and also the time its penetration trough the sample directly exposed on the fire action. The scheme of apparatus used in the test shown Figure N° 1.

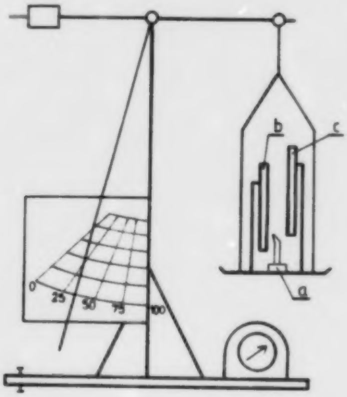


Figure 1. Scheme of apparatus for testing the combustibility by gravimetric-ignition method
a - burner, b, c - tested samples

In this investigations were used samples in the form of plates with dimmensions 15x150x300mm, for each material plot 10 such sample pairs have been prepared. The samples were made from material 25mm thick, nominal thickness 15mm has been obtained trough outside layers planing.

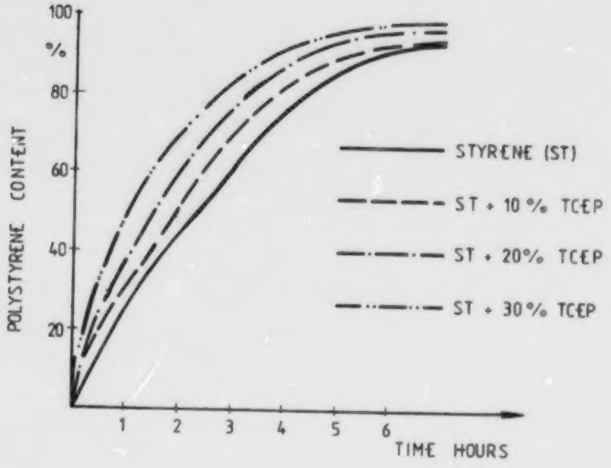
RESULTS

Effect of combustion inhibitots on the styrene polymerisation course

The presented in grafical form results suggested (Figure N° 2), that used in the investigations organophosphates catalycally influenc on reaction of polymerisation of styrene. The courses of curves show more distinct effect of TDCPP while the action of TCEP is less distinct.

Taking as the refference level the time in which polystyrene content in polymerising mixture was 50%, to the 10% addition of TDCPP causes acceleration of polymerisation process about 30%. At higher contents of TDCPP in styrene was observed respectively higher acceleration of reaction.

In case of TCEP is was observed that 10% addition of this



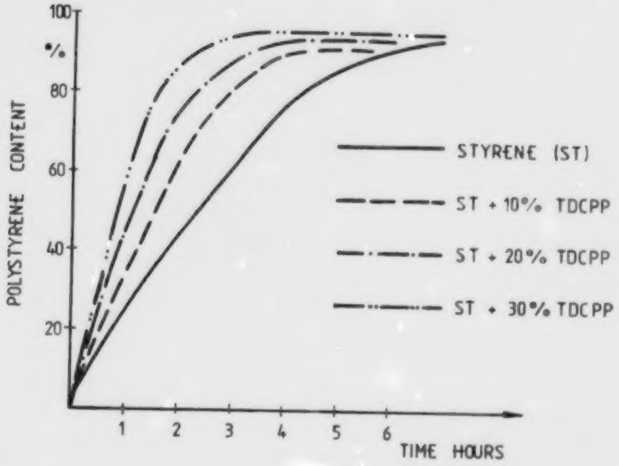


Figure 2. Effect of trichlorethylphosphate (TCEP) and tridichlorpropylphosphate (TDCPP) addition to the styrene (ST) on its polymerisation course

fire-retardant causes acceleration of polymerisation process about 20%. Higher contents cause shortening of the appearance of polystyrene in slightly higher degree.

Similar phenomenon was observed by Gajdziński and Lutomski (1980) in studies on increase of biological durability of wood-polystyrene composite. There was suggested, that catalytic influence of some additions could be favourable for the production of this composite. It is adventageous to shorten polymerisation time, and positive effect can be achieved also in lower temperature, what is bound with the decrease of energy consumption. The lowering of the losses also can be expected by decrease of monomere styrene volatilization, before the whole process is concluded, what can take place in lower reaction temperature.

It is to be added, that the attemps to initiate the styrene polymerisation with addition of fire-retardants alone, without proper initiators and catalysts did not give positive result. During heating of styrene with addition TCEP and TDCPP in quantities 10 + 40% in samples there was not found presence of polystyrene.

Effect of addition of fire retardants to styrene on the static bending strength of wood-polystyrene composite

In the presented in Table 3 results it can be seen, that in comparison to the wood-polystyrene composite, static bending strength of such material obtained with the share of styrene with addition of TCEP and TDCPP is in majority of cases a little lower. Difference in extremal case is 19 MPa, that is above 13%.

Table 3

Effect of trichlorethylphosphate (TCEP) and tridichlorpropylphosphate (TDCPP) content in styrene (ST) on the static bending strength of wood-polystyrene composite

Kind of wood	Impregnation liquid	Static bending strength	Standard deviation	Variation coefficient V
		MPa		%
pine	Styrene	143	11,4	7,8
	ST + 10% TCEP	132	10,7	8,1
	ST + 20% TCEP	130	10,1	7,8
	ST + 30% TCEP	124	11,0	6,9
	ST + 10% TDCPP	144	10,0	8,2
	ST + 20% TDCPP	142	11,6	8,1
	ST + 30% TDCPP	138	10,8	7,9
alder	Styrene	107	7,1	6,7
	ST + 10% TCEP	108	6,9	6,4
	ST + 20% TCEP	105	9,4	8,9
	ST + 30% TCEP	100	12,4	11,5
	ST + 10% TDCPP	101	8,9	8,9
	ST + 20% TDCPP	98	9,1	8,8
	ST + 30% TDCPP	95	8,3	9,9

The results after statistical analysis are showing that found differences are not significant, because in all cases the significance index of difference m_d was lower than 3. That means, that in the limits up to 30% addition of both fire-retardants to the styrene did not effect on the static bending strength of wood-polystyrene composite. Tosiek (1989) in more wide range made assessment of influence addition of TDCPP to styrene on some physical and mechnical properties of wood-polystyrene composite. In the said investigations made with the use of pine and birch wood was verified slight decrease of static bending strength, there was observed simultaneously distinct decrease of hardness in comparison to the material obtained without TDCPP. Dimmensional stability, beeing important index of quality of wood-polymer composite, in case of 30% addition of TDCPP to styrene differed only slightly from stability of such material without addition of fire-retardant.

Influence of organophosphates on the pine and alder wood combustibility

The results of investigations obtained by radiation method are tabulated in Table 4. As it can be seen impregnation of pine and alder wood with TDCPP is lengthening the combustion time for samples respectively 25 and 5%. Distinct decrease was observed in the independent time of combustion of impregnated samples.

Table 4

Effect of trichlorethylphosphate (TCEP) and tridichlorpropylphosphate (TDCPP) content in wood on the fire-resistance determined by radiation method

Kind of wood	Fire-retardant content in wood	Characteristics of combustibility	
		Time of the ignition	Time of the independent combustion
	%	sec	
pine	-	40	288
	TCEP 32,1	94	215
	TDCPP 31,6	50	113
alder	-	64	282
	TCEP 34,7	73	185
	TDCPP 36,4	67	157

At the same more or less contents effectiveness of TCEP was higher, because in case of alder wood lengthening of inflammation time of sample reaches 14% and in case of pine wood above 100%. The independent combustion time of impregnated samples with this chemical was also shorter. In this way manifested fire-protective character of both investigated chemicals. TCEP has retarded on the moment of inflammation of samples, while in case of TDCPP appeared distinct effect of selfextinction of the flame.

Combustion of wood-polystyrene composite

The results of measurements of mass losses conducted with the use of gravimetric-ignition method as the time function are presented on the Figures N° 3 and 4. The analysis of the curves on those drawings allows to include that the wood-polystyrene composite is characterised by lower in comparison with natural wood combustion speed. For natural wood maximum mass losses occured after 20 minutes, for the composite after 25 minutes. The final burn out of investigated woo-polystyrene composite was a little higher from natural wood. The higher combustion speed of wood without syntetic polymer can be explained by the more favourable conditions for the oxidation reaction of wood. In case of composite free spaces were filled out by the polymerised resin, hindering, especially in the first phase of combustion, access of oxygen inside sample and exudation of combustion gases.

Presented on the Figures N° 3 an 4 results indicate that the addition to styrene such chemicals as trichlorethylphosphate and tridichlorpropylphosphate are causing decrease of speed of combustion of wood-polystyrene composite, and lowering final mass losses. The observed effects are linked with the content of mentioned compounds in styrene and also with kind of wood used to produce of composite. For alder wood impregnated with styrene with addition of TCEP the effect of quantity of this fire-retardant on the combustion process is less distinct than for the pine wood. The combustion speed of composite obtained from pine and alder wood impregnated with mixture of styrene and TDCPP are similar.

Czechowski and Zakrzewski (1983) explained fire protective action of trichlorethylphosphate present in wood-polystyrene composite by the shift of begining of thermal destruction of material in the direction lower temperatures. The shift is greater at higher contents of fire-retardants. Simmilar effect was observed in the investigations on the composite obtained from pine and birch wood, ammeliorated with polystyrene containing 30% of tridichlorpropylphosphate (Tosiek 1989).

On the basis of presented on Figure N° 5 results, showing mass losses of investigated materials after 15 and 30 minutes of of combustion test it can be observed that composite obtained from pine sapwood and styrene with addition of organophosphates is more thermally resistant that alder-polystyrene composite. In course of tests it was also observed, that the heating of this material was accompanied by rampant flow of melted polystyrene, which was less distinct during investigation of pine wood composite. The flowing out from the samples of polysterene was subjected to fast depolymeristion and combustion accompanied by the considerable amount of smoke and soot. The observed facts we can attempt to link with various anatomical structure of pine and alder wood in the same with various their impregnability. Easy saturation of alder wood is favourable feature in the impregnation wit various liquids, while in the combustion process of composite causes that polystyrene at hihger temperature easily flows from material. This is certified on the curves of combustion speed of natural wood of pine and alder and composites produced of them (Figures N° 3 an 4).

Additional information on behaviour of tested composite materials in fire could be given by the results measurements presented in Tables N° 5 and 6. It can be seen distinctly, that with in-

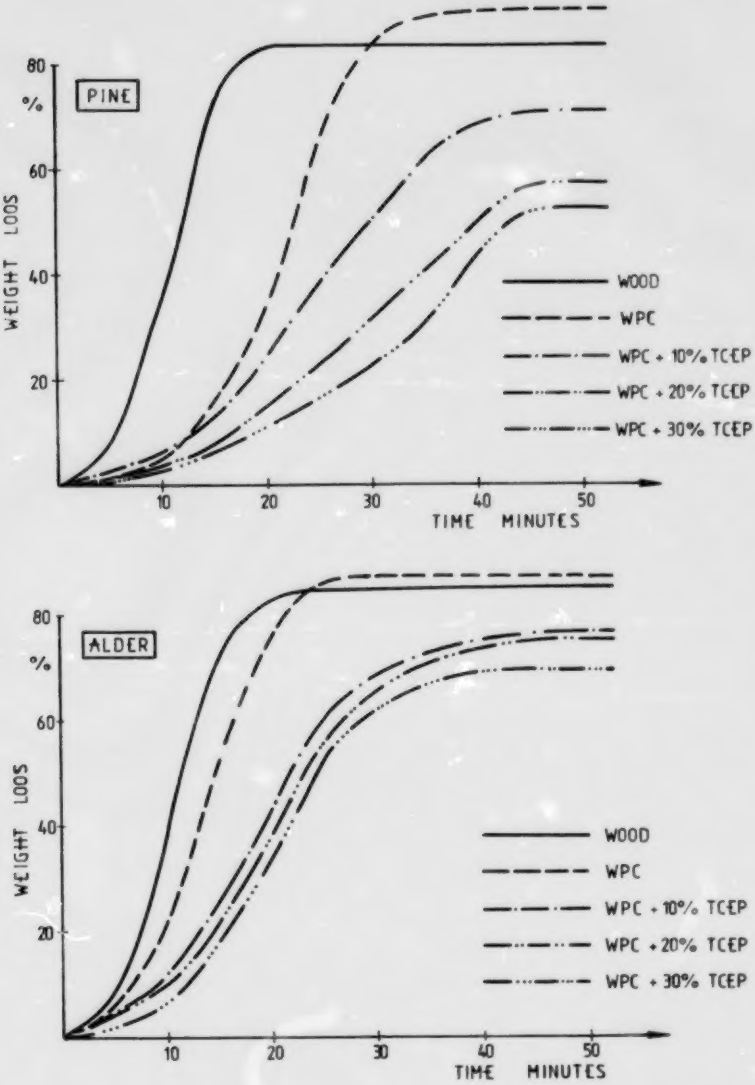


Figure 3. Effect of trichlorethylphosphate (TCEP) content in styrene (ST) on the weight loss of pine wood, alder wood and wood-polystyrene composite (WPC) in testing the combustibility by gravimetric-ignition method

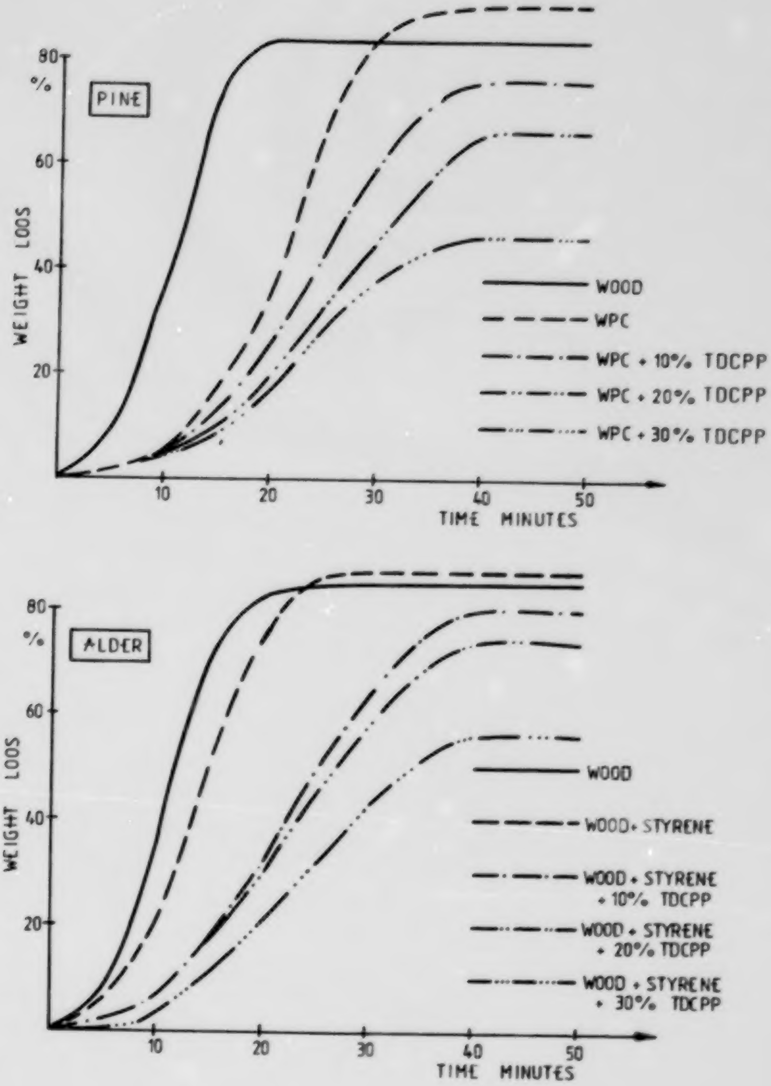
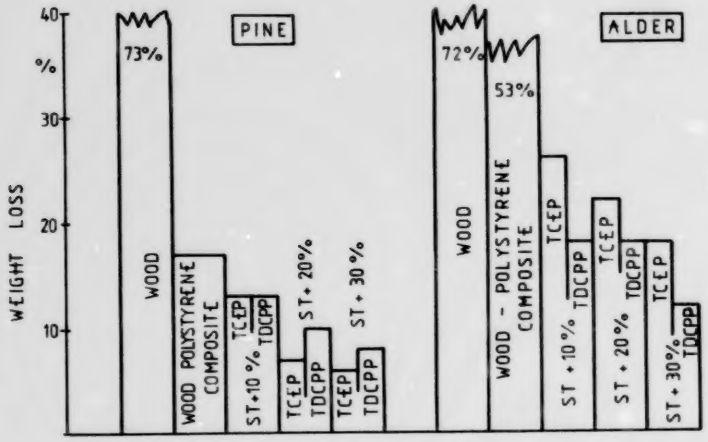
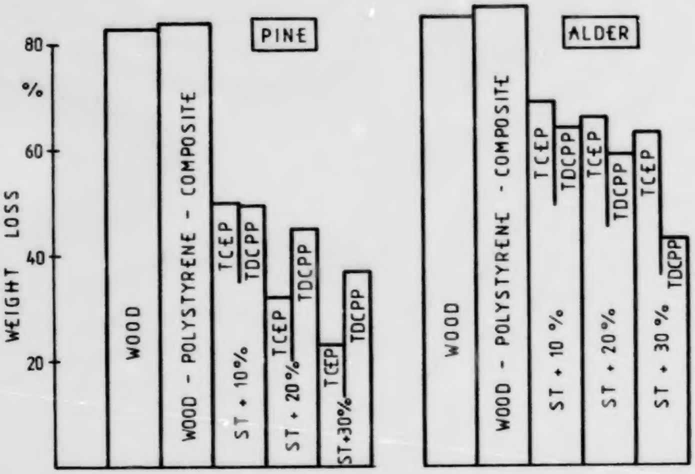


Figure 4. Effect of tridichlorpropylphosphate (TDCPP) content in styrene (ST) on the weight loss of pine wood, alder wood and wood-polystyrene composite (WPC) in testing of the combustibility by gravimetric-ignition method



AFTER 15 MINUTES



AFTER 30 MINUTES

Figure 5. Effect of trichlorethylphosphate (TCEP) and tridichlorpropylphosphate (TDCPP) content in styrene (ST) on the weight loss of wood-polystyrene composite after 15 minutes and 30 minutes testing of combustibility by gravimetric ignition method

Table 5

Additional criteria of the effectiveness of protecting on wood-polystyrene composite with trichlorethylphosphate (TCEP) against the action of fire determined by gravimetric-ignition method

Kind of wood	Composition of impregnation mixture	Time of independent combustion on sample after		Time needed for the appearance of flame on the opposite sample	Time needed for the penetration of flame across the sample
		5 min	15 min		
		sec			
pine	-	180	180	250	550
	Styrene (ST)	180	180	453	900
	ST + 10% TCEP	12	180	464	1 780
	ST + 20% TCEP	4	110	508	2 020
	ST + 30% TCEP	-	60	655	2 300
alder	-	180	180	175	570
	Styrene	180	180	194	621
	ST + 10% TCEP	180	180	288	988
	ST + 20% TCEP	110	180	289	1 023
	ST + 30% TCEP	100	180	356	1 060

Table 6

Additional criteria of the effectiveness of protecting on wood-polystyrene composite with tridichlorpropylphosphate (TDCPP) against the action of fire determined by gravimetric-ignition method

Kind of wood	Composition of impregnation mixture	Time of independent combustion on sample after		Time needed for the appearance of flame on the opposite sample	Time needed for the penetration of flame across the sample
		5 min	15 min		
		sec			
pine	-	180	180	175	568
	Styrene (ST)	180	180	453	990
	ST + 10% TDCPP	53	180	571	1 659
	ST + 20% TDCPP	24	147	483	1 937
	ST + 30% TDCPP	15	134	404	2 401
alder	-	180	180	255	550
	Styrene	180	180	174	621
	ST + 10% TDCPP	112	180	307	1 565
	ST + 20% TDCPP	93	180	365	1 600
	ST + 30% TDCPP	78	143	414	2 027

crease of organophosphates content in styrene decrease time of creation of insulation layer. This is certified by the times of independent combustion of samples after 5 and 15 minutes of test duration. It can be observed also increasing together with increase of content of fire-retardants in styrene the tendence in time value, after which takes place the flame jump on the opposite sample. In case of 30% content of TCEP it was stated even total retardation of combustion of material after flame removal in the 5th minute and after 60 seconds in the 15th minute of measurement.

The conducted tests allow to state, that in the process of production of pine-polystyrene composite, addition to styrene 20 ÷ 30% of such organophosphates as trichlorethylphosphate or tridichlorpropylphosphate allws to obtain material with higher fire durability than natural wood and wood-polystyrene composite. This durability in case pine wood is specially evident during 15 minutes from test start (Figure N° 4). In this period mass losses during combustion of this material samples did not pass 10%. Begining in this time fire fight action creates chances of its control. In anti-fire practice it its taken that fire could be fast and effectively controlled, if the action of its fighting will begin in time of 5 minutes from its arise (Lindner, Struś 1974).

CONCLUSIONS

1. Addition of trichlorethylphosphate and tridichlorpropylphosphate to styrene in quantities up to 30% is not hindering course of its polymerisation and did not essentially influence static bending strength of wood-polymer composite.

2. The presence in styrene of trichlorethylphosphate and tridichlorpropylphosphate in quantities 20 ÷ 30% causes decrease of combustibility speed of wood-polystyrene composite and improves its thermal durability characteristics, especially in first 15 minutes of combustion.

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STUDIES OF WOOD-COMPOSITE HAVING RESISTANCE AGAINST FLAMMABILITY AND BIODEGRADATION

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SUMMARY

There is a growing realisation of the need for an effective fire retardant cum preservative formulation which should not cause adverse changes in the properties of the treated material. A phosphated acid copper chrome composition has been developed which has been found quite satisfactory in relation to the above need. Phenolic bonded plywood directly from the hot press is impregnated in the waterborne composition and within a reasonable period satisfactory retention is obtained. The impregnated material is dried at a lower temperature to reduce the moisture content. Satisfactory fire resistant and antifungal properties have been observed with the treated plywood. The material is not hygroscopic. It has satisfactory leach resistant properties which is substantiated by testing the fire retardant properties of the material after soaking in water for 7 days. The reduction of the strength of the treated plywood is within a reasonable limit. The glubility and paintability of the treated plywood are among other advantages of the composite. These properties of the composition as well as its ease of application, makes it a good candidate for commercial exploitation.

Key Words : Fire retardant, preservative, phenolic bonded, leach resistant.

INTRODUCTION

Wood and wood based panel products are primarily building materials and because of their superior behaviour in functional properties, such as, strength, insulation, acoustic and the like, they are used in roofing , flooring, panelling, partitions and separations, constructional works, in defence and naval requirement and so on. The deterioration of wood material brought about by both thermal and bio-degradation is a source of huge loss of life and property and, as such, increasing attention has been given for its prevention from these hazards. Fire retardants reduce flame spread and prevent wood from supporting its own combustion while preservatives make wood toxic to organisms those are responsible for its degradation.

In the recommendation emanating from the session on "Fire performance of wood" during the last IUFRO D5, Forest Products Conference held at Sao Paulo, Brazil due emphasis was given to wood protection both from fire and biological attacks.

Treatment of wood and wood products with emulsion of gamma isomer of benzene hexachloride along with sodium pentachlorophenate is an usual and accepted practice to reduce fungus and insect attack[12]. Various metal salts used either alone or in combination with each other and also with fluorine, arsenic or with boron containing compound have also found acceptance as wood preservatives[8]. Water-borne preservatives, such as, ammonical copper arsenite (ACA) and chromated copper arsenate (CCA) have found wide application in the preservation of wood material.

In the case of most waterborne preservatives, a chemical reaction occurs between the wood and the water soluble salts which results in virtually complete precipitation of an insoluble preservative material in the wood. The borax-boric acid mixture is quite effective against a wide range of wood destroying fungi[5], but because of its relatively high solubility in water, it is leachable from timber.

Efforts to improve the performance of fire retardants have led to the screening of a number of inorganic salts and recently, to the development of formulations based on organic compounds[6,9,13,14,17,19,20,22].

Studies on the thermal degradation of wood provide different theories for the action of fire retardants in controlling the degradation. In spite of the current understanding inflammability and its resistance by the application of suitable chemicals in wood, present commercial practice still depends on a number of inorganic chemicals, such as, borax, boric acid, ammonium sulphate, ammonium phosphate, zinc chloride, which have been recognised as fire retardants for more than a century. Despite their several disadvantages they continue to be used to protect wood against fire due to their inexpensive nature and effectiveness.

Rapid sustained degradation of wood by combustion follows usually the sequences :

(i) Wood is heated to its decomposition point, (ii) wood decomposes to flammable gases and (iii) flame is propagated by these gases. Interference with one or more of the above steps can retard or stop combustion. Effective fire retardants act in more than one manner.

It is also desirable that an ideal fire retardant-cum-preservative treated wood-based panel materials should not cause any adverse changes in the properties of the treated materials[10]. The related properties important in the acceptance of fire retardant wood products include hygroscopicity, strength, paintability, gluability, leach resistance and the like. The present paper reports on the development of fire retardant plywood panel with preservative property against borers and fungus and the study of the treated products in relation to the above properties. A process has been developed in which phenolic resin bonded plywood is impregnated in waterborne fire retardant-cum-preservative composition by following the simple technique of impregrating plywood panels directly from the hot press in the cold solution of the above composition[20]. This avoids the use of costly vacuum-cum-pressure impregnation method.

MATERIALS AND METHODS

A phosphated acid copper chrome composition was developed and 15 percent aqueous solution of the same was used for impregnation of plywood panel. The pH of the solution was adjusted between 2.5 & 3 to get a clear solution. Phenol formaldehyde resin bonded plywood panels of dipterocarpus species, removed from the hot press were directly impregnated in the above fire retardant-cum-preservative composition in a tank. This was followed by drying in the seasoning kiln at about 60-65°C to reduce moisture content of the panel to 8-10 per cent. The resultant product is flame retardant as well as resistant to fungus and insect attack.

Determination of retention in the plywood :

A strip of 1" width is cut from the panel to be treated and samples of 1"x1" of definite thickness were made out of it. Corresponding samples of treated material were also made and from the difference in weight of the treated and non-treated samples, retention of fire-retardant-cum-preservative composition in the panels was calculated. It has been observed that about 40-50 Kg/m^3 retention is required for satisfactory results. 2-3 hours impregnation time is sufficient to give that retention.

TESTS & RESULTS

Testing of fire resistance property was carried out according to Indian Standard Specification[11]. Hygroscopicity of the treated plywood was tested by equilibrating the plywood samples to the corresponding humidities in air tight dessicators containing moist sodium carbonate, ammonium nitrate and magnesium chloride to get the relative humidities of 90%, 65% and 45% respectively.

To test the glue shear strength of the treated and untreated plywood panel was tested according to IS standard 1734[11].

Results of Fire retardant properties of the treated plywood are shown in Table-I. Test results conform according to IS : 5509[20].

Results of flame penetration test both for treated panels without leaching and panels after 7 days leaching in water are shown in Table II. Results for control is also given in the table. The results show that the treated panels possess fairly good leach resistant property. When the treated panel is under action of water for a considerable period, the preservative-cum-fire retardant composition is not washed away; a substantial part of it is retained in the plywood panels.

The treated plywood was found to give up the moisture quickly with the lowering of humidity in the surrounding atmosphere. The moisture contents of the treated and untreated plywood at different humidities are shown in the Table III.

The glue shear strength and the tensile strength of the treated plywood are shown in Table IV and Table V respectively. When compared with the control, the values are found to be reduced, although within reasonable limits.

The paintability of the treated plywood is quite satisfactory. The treated panels can be painted by suitable paints, if needed.

The gluability of the fire-retardant-cum-preservative treated plywood is also satisfactory. By using rubber based adhesive or PVAc adhesive decorative sheets can be laminated over the fire retardant-cum-preservative treated plywood.

The treating composition developed is resistant against fungus too. The toxicity test of the composition as described by Schmitz[21] has been performed by introducing a known concentration of the composition into a weighed amount of malt-agar in a flask after duly steam sterilization of the flask. The content after being poured into a sterile petridish is allowed to harden. A square of growing fungus (Polyporous versicolor) is placed in the center of the petridish and examined for growth over a period of two weeks. No growth develops on the petridish containing the culture medium with the composition but resumes growth when in contact with malt-agar without the composition.

DISCUSSION

There are a number of formulations available for imparting resistance against fungus and borers to wood and wood based product. There are formulations to make wood fire retardant too. Necessity has also been felt to develop wood based products, resistant to both thermal and biodegradation. It is hoped that the product discussed in the present paper can meet the same demand.

As the preservative component, acid copper chrome has been used in the composition. It is a multiple preservative containing copper sulphate, chromic acid and sodium dichromate. The addition of dichromate serves two purposes : it reduces the corrosiveness of copper sulphate and it also precipitates the soluble copper as insoluble product, so that when wood has been dried after treatment, the preservative will not leach out in wet condition. The toxicity of acid copper chrome (ACC) is wellknown and the said property of the phosphated ACC of the present composition has been tested and found satisfactory. Wood destroying fungi decay wood by the secretion of extracellular enzymes. These enzymes depolymerise the carbohydrates and, in some cases, the lignin components of wood to smaller molecules which can be metabolized further by intracellular enzymes of the fungi[15,24]. Fungicides present in the preservative kill or inhibit the growth of fungi. Susceptibility to copper tolerant fungi is the main weakness of ACC preservative and the application of arsenic pentoxide in the composition may prevent the attack by copper tolerant fungi.

The mechanism of the fixation reaction is suggested to be as follows[7] : (i) Hexavalent chromium is fixed in the wood by formation of loose compounds of hexavalent chromium with wood extractives and by the formation of difficultly soluble chromates such as, Na_2O, $4CuO$, $4CrO_3.3H_2O$; (ii) Partial reduction of the chromate by the wood causes an increase in pH, hydrolysing the alkali chromate to basis chromate, (iii) Trivalent and hexavalent chromium may combine to form insoluble chromic chromate, XCr_2O_3, $YCrO_3.2H_2O$.

A number of reactions of different wood constituents with copper in the composition have been suggested by different workers[1,2,3]. Whichever wood component is responsible for copper complexation, the reaction is co-existing with the reduction of hexavalent chromium, the reaction which proceeds with time. Effective resistance to the borer attack can be imparted by employing ACC preservative[16,18]. However, there is considerable variation in the effectiveness of the preservative when different wood species are used.

Phosphorous is one of the most abundantly used element for imparting fire retardance to wood material. Mono and diammonium phosphates have been found highly effective as five retardant chemicals used to-day. The phosphated ACC discussed in the present work is also highly effective towards flame resistance as it is evident from the test results (Tables I & II). Even after 7 days water treatment the treated plywood retains quite satisfactory fire retardant property.

Thompson[23] found that wood failure of ACC treated sweetgum veneer specimens bonded with phenolic resin is affected slightly in wet samples. Similar result has been obtained with phosphated ACC treated samples (Table IV). The dry and wet glue shear strength and wood-failure are not much affected by the treatment.

The strength properties of the fire retardant-cum-preservative treated plywood are known to be affected as mentioned in the literature[4,19]. Acids cause hydrolysis of the cellulose components of wood with resultant loss in impact resistance. Alkalies, on the other hand, dissolve hemicellulose and lignin and reduce the hardness and stiffness of wood. The acidity of the present composition is fairly low and the tensile strength of the treated plywood has been found to be affected slightly although within the limits (Table V).

CONCLUSION

The reason for the development of a preservative-cum-fire retardant composition was the growing realisation of the need for an effective 'two in one' formulation which should not cause adverse changes in the properties of the treated material. The present composition is waterborne, not highly acidic and the resultant product being fairly satisfactory towards gluability, paintability alongwith its preservative and flame resistant properties. It is neither hygroscopic nor leachable. Plywood can be impregnated with the preservative-cum-flame resistant solution without using the costly vacuum-cum-pressure impregnation process. Satisfactory retention can be obtained within a relatively short period by the easily applicable and simple process. In view of the above advantages the composition as well as the application procedure have commercial potential.

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TABLE I

Test results on fire-retardant-cum-preservative treated plywood (tested as per IS : 5509 - 10.3.1; 10.3.2 & 10.3.3)

Sl. No.	Ply and thickness in mm	Moisture content of tested sample (per cent)	Method of test of wood	Average time required
1.	7 ply; 12 mm	12	Flammability	more than 60 mins*
2.	"	"	Flame Penetration	40 "
3.	"	"	Rate of burning test	28 " (from 30 to 70 per cent loss in weight)

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*The edges of the samples were treated with the fire retardant-cum-preservative composition prior testing.

TABLE II

Test results on fire-retardant-cum-preservative treated plywood with and without leaching (Flame Penetration)

Sl. No.	Ply and thickness in mm	Description	M.C. of the samples tested (per cent)	Average time for flame penetration	Required time according to IS:5509
1.	7 ply; 12 mm	Samples without leaching	14	45 mins	30 mins
2.	"	Samples after 7 days leaching in water	14	31 mins	"
3.	"	Control (without fire retardant-cum-preservatives treatment)	14	17 mins	"

TABLE III

Behaviour of fire retardant-cum-preservative treated plywood samples under different humid conditions

Sl. No.	Description	Average m.c.,(per cent) under equilibrium at 40% relative humidity	Av. m.c. under equilibrium at 65% rel. humidity	Av. m.c. at 90% rel. humidity
1.	Control (without treatment)	12	13	14
2.	Samples with 6% F.R.-cum-Preservative Composition	14	16	18
3.	Samples with 10% F.R.-cum-Preservative composition	15	17	20

TABLE IV

Effect of fire retardant-cum-preservative treatment on the Glue Shear Strength of Plywood (Av. of 6 samples)

	Dry glue shear strength		Glue shear strength after 8 hrs boiling in water	
	Failing load (Kg)	Wood failure (per cent	Failing load (Kg)	Wood failure (per cent)
Control (without treatment)	160	75	135	60
Fire-retardant cum-preservative treated	125	60	110	80

TABLE V

Effect of fire retardant-cum-preservative treatment on the tensile strength of the plywood (Av. of 6 samples)

Control (without treatment)		Fire retardant-cum-Preservative treated	
Along the grain	750 kg/cm^2	Along the grain	680 kg/cm^2
Across the grain	605 kg/cm^2	Across the grain	505 kg/cm^2

WOOD FIRE PROTECTION
-HISTORY AND FUTURE

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SUMMARY

Protection of wood from fire has a very old history. Empirical approaches to searching the fire retardants of wood had prevailed for a long time. In this century the theories that have been developed are serving also in the practice for unflammable treatments and testing of fire retardants as well. The problems of assuring the quality of utility properties of treated products are prevailing. In future, the most important seems to be the system's approach to the fire protection treatments. Internationally valid standards for complex protection are necessary.

Keywords: Fire protection, Fire retardants, Testing, Properties of treated products, Fire protection of composites.

1 Early History and Introduction to the Problems

Fire protection has very old history, the begining of which could be found at the same time as has been the discovery of fire. In the ancient period for reducing of flammability of wood coatings applied to its surface and solutions for impregnation were known. Empirical approaches to wood-protection were dominating throughout long ages untill 1880 when Gay Lussac described its theory of isolated layers and its dilution theory [1,2]. Gay Lussac was able to build his theories on the model of the flame-burning /model of Davy's candle, 1778-1829/, which was, later on, developed by Faraday /1860/, meanwhile the acceptable model for the smoldering combustion of cellulosic materials is still missing. On the other hand, Gay Lussac has already justified the use of ammonium phosphates and borates which are thought to be mostly employed wood-fire retardants so far [1-7].

In this century the knowledge on the burning of cellulosic materials has been considerably extended [4,11,12]. Nowadays we can identify a large number of efficient fire retardants [5,9-11]. Substances containing the P-N-X in a single molecule were synthetised, and intumescent coatings providing stable foams of high isolation compabilities were developed [8,9]. In the same period there were many works directed to elucidation of the burning process of the pure and modified cellulose, based on the levoglucosane and dehydration theories [4,11,17].

Serebrenikov et al., CNILCHI, Moscow [16] suggested the chemism of the action of fire retardants, mainly phosphates.

The systematic research carried out into wood flammability and fire retardation with the aid of inorganic salts started in the years of 1930-35, in Forest Product Lab., Madison. There were tested about 130 preparations from the aspect of ignitability, heat release, flame spread and smoke density. A weight-loss was determined in the so-called fire tube /Truax T.R., Harrison C.H. and Hunt G.M./ [14,15].

Later on, there have appeared some new problems concerned with testing methods, the results of which should better correlate with observations performed during the real fires. The experience showed that requirements to the quality of protected materials have not been fulfilled, especially with regard to [10,12]:

- leaching off,
- hygroscopicity,
- resistance to fungi,
- decline in strength properties,
- decrease in the strength of glue joints,
- corosion of metal joints,
- higher smoke density and toxicity.
- depreciation of esthetic surface.

2 The Use of Inorganic Salts as Fire Retardants

Research on fire-retardation in Madison kept some continuity also in 60-ties thanks to F.L.Browne, W.K.Tang, H.F. Eickner, E.L. Schaffer, J.J. Brenden etc. [10,11,20-31]. One of the most important results obtained in Madison Lab. was the division of inorganic salts according to their effects on the thermal degradation of cellulosic materials into four groups, Table 1.

This classification /Table 1/ has been well confirmed by the results of thermal analysis in many laboratories [3,21-24,32-40]. The results of TG and DTA are shown in Fig.1.

Table I Four groups of inorganic salts according to thermal analysis results

Group	Effectiveness at 250 °C	 at 350 °C	Example
I	not significant	retardation	$Na_2B_4O_7$
II	accelerat. /dehyd./	retardation	$NH_4H_2PO_4$
III	not significant	not significant	NaCl
IV	slight acceleration	not significant	Na_3PO_4

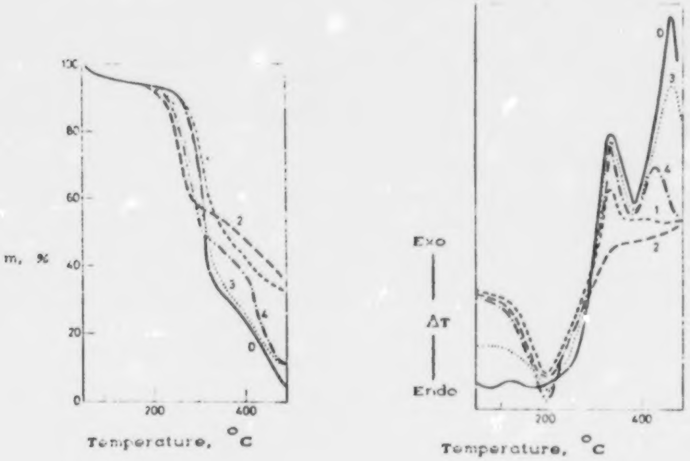

Fig.I TG and DTA curves of spruce wood impregnated with various inorganic salts; o - no treatment, I - $Na_2B_4O_7$, 2 - $/NH_4/H_2PO_4$. 3 - NaCl, 4 - K_3PO_4.

The effects of salts depend not only on character of anion but also that of a cation. Ammonium phosphates havebeen found very effective fire retardants of cellulosics, but ammonium chloride has been not. In the group of chlorides the effectivity depends on the ionnic strength of salts Fig.2 [36-39].

At present time we may conclude that efficient wood fire-retardants belong to the first and the most frequently to the second group of the Madison classification. To choose the suita-

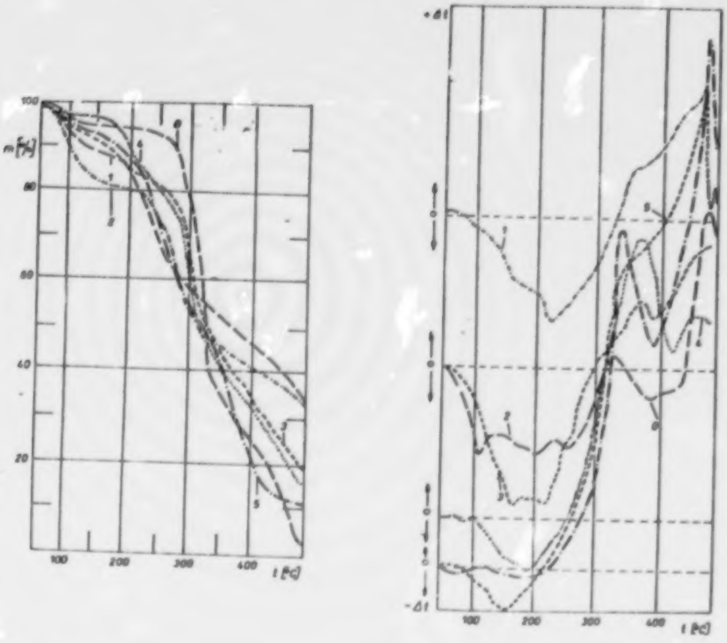

Fig.2 TG and DTA thermograms for wood impregnated with some chlorides. The flow rate of oxygen - 7 liters/hour, the speed of heating - 10 °C/min.
1 - $ZnCl_2$, 2 - $CaCl_2$, 3 - $AlCl_3$, 4 - NH_4Cl, 5 - $FeCl_2$.

bility of a particular salt for the purpose of the fire retardation of individual wood products is still a complicated matter [11,41-43]. The main pyrolysis of wood starts at temperatures above 250 °C [18,34,43]. This condition is complied with salts of the second group which are, at the same time, responsible for undesirable unstability in treated wood products at low temperatures [10,11,41]. During the heating of treated wood the following reactions occur [41,44]:

- hydrolysis of acylic and glycosidic bonds,
- thermooxidation,
- dehydration reaction /inter, -intramolecular/,
- depolymerization of polysaccharides /with glycosans formation/,
- non-specific degradation of -C-O- and -C-C- bonds.

None of the reactions indicated above does result in a higher stability of cellulosic materials. The hydrolytic degradations of polysaccharides result in decline of strength properties of treated product [10,12,41] and may be due to acceleration of thermoxidation [41,44]. Samples of cellulose impregnated with acidic salts showed a higher rate of thermoxidation than untreated sample, Fig.3.

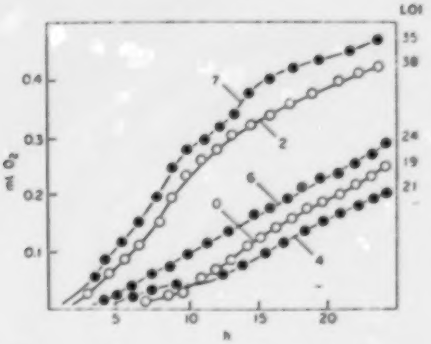

Fig.3 Oxygen consumption /uptake/ on heating different cellulose samples at 150 °C;
o - without treatment, LOI 19, 2 - impregnated with $NH_4H_2PO_4$, LOI 38, 4 - cyanoethylated, LOI 21, 6 - grafted, LOI 24, 7 - impregnated with $ZnCl_2$, LOI 35.

The favourable reactions may be considered those which lead to the limitation of the rate of depolymerization of the cellulosic components and lead to the formation of less-flammable volatiles. Reactionsof dehydration lead to the higher yield of char and to the formation of less flammable volatiles than are those which are formed by depolymerization. An important effect of salts would be obtained by keeping the temperature under 310° at which cellulose begins to rapidly pyrolyze [43].

Thermoxidation affects the temperature profiles as a highly exothermic reaction. The changes in composition and concentration of volatiles are limiting for flamming, smoldering, overflashing at certain oxygen concentration level, Fig.4 [42].

The results shown in Fig.4 indicate four areas which belong to the different conditions for propagation of flamming or smoldering:

i/ at these temperatures and oxygen concentration any propagation is not possible,

ii/ the propagation of flamming is posible after pilot ignition,

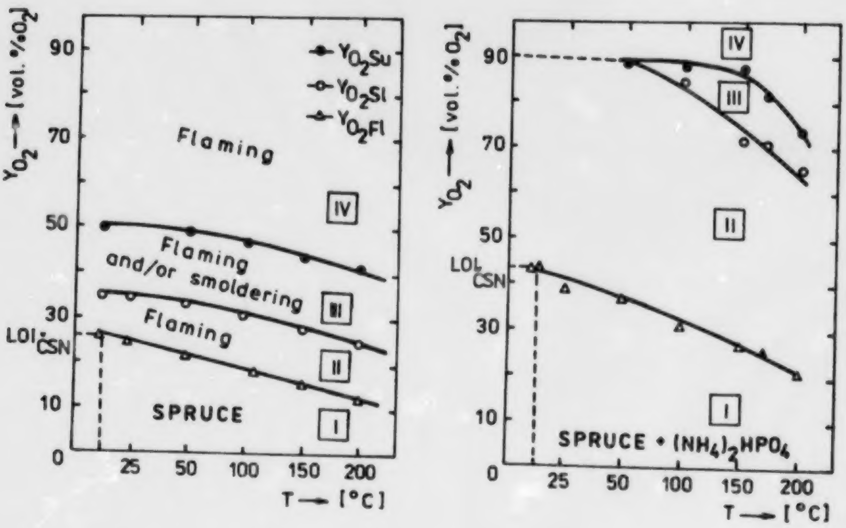

Fig.4 Variations of the mode of burning of spruce wood with oxygen concentration and temperature used /Y_{O_2} Sl - lower limit of smoldering spread; Y_{O_2} Fl - lower limit of flaming spread; Y_{O_2} Su - upper limit of smoldering spread/. A - untreated wood, B - impregnated with /$NH_4/_2HPO_4$.

iii/ the propagation of flamming or smoldering is possible after extinction of the flame,

iv/ only flamming is posible, the smoldering is chanched into flamming spontaneously [42].

3 Surface Treatment and Modification of Properties of Composites

Wood composites /such as plywood, fibre board, particle board/ can be treated into material with decreased flammability using basically the three following procedures [53]:

- impregnation of wood particles, fibres and veneers [50-53], It is to be noted that surface protective layer should not depreciate the estetic quality of wood products, it should be transparent and highly stable /before and after weathering/ [54].

4 Properties of Treated Products, Complex Effects of Protection

The products which undergo an unflammable treatment are more expensive and therefore it is clear that their properties should be better than those of the untreated products. In the past, this principle was not always accepted and especially the wood products impregnated with acidic salts were characterized by a higher hygroscopicity, a lower resistance to leaching and by essentially reduced strength properties [10,11]. This properties are diminished in the case of heating of impregnated product, above 100 °C [42].

The progress in improving the properties of commercialy fire-protected cellulosic materials has been made in the past decades. There are several possibilities for such improvement using the formulation:
- which form insoluble buffering systems [11,42],
- which contain urea, melamine, guanidine or dicyandiamide resins [52-54,73],
- which contain colloidal additives such as soluble derivatives of cellulose [42].

The problems of the effects of fire retardant treatment in strength properties under elevated temperatures is included in this congress, in our session [63].

The effect of antipyrenes is combined with the fungicidal and insecticidal action [64-66]. There exist water-soluble composition as well as composition soluble in organic solvents which have a positive influence on the flammability parameters and on the biocidal stability as well.

The smoke and toxic products of combustion are problems of growing concern which must not be overlooked in developing fire retardants [11,47]. Untreated wood gives combustion products which are less toxic than those evoluted at combustion of some synthetic polymers, Fig.6.

- addition of fire retardants to the matrix /adhesive/ [55,57],
- use of coating /surface treatment/ [54,56].

The impregnation of veneers and wood particles may lead to a considerable reduction of flammability of final products. However, their production has become complicated and in the event of using water soluble inorganic salts the problem of quality of products must be solved.

The modification of the polymeric /synthetic/ matrix enables water-insoluble retardants containing a P-N-X synergetic system to be used [5,9]. Phenol-formaldehyde adhesives modified with a triarylphosphate [57] and polymeric isocyanate adhesives were successfully modified with a triethylphosphite [55]. A desirable effect can be achieved by filling the synthetic component either with $Al_2O_3.H_2O$ or $MgCO_3$ [57]. Especially $Al_2O_3.H_2O$ causes a remarkable change in thermal conductivity of the synthetic component and prevents it from local overheating. According to recent results[83] thermal conductivity and limited oxygen index of polyolefins change suddenly with the certain content of Al_2O_3.

Other possibility to reduce flammability of synthetic polymers is addition of organophosphorous monomers, e.g. bis-/2-chlorethyl/-vinylphosphate to the polymerizing system [58].

The effect of surface coating can be accounted for by means of barrier and thermal theories [1,5,9,11,54]. The most effective insulating layer is formed in the case of heating such materials which are coated with intumescent layers [5,9,54,59-62]. The efficiency of such coatings depends on expanding factor and thermal properties of foam /its polymeric skeleton/ [59-62]. Thermal analysis is the method for examination of intumescent coatigs, Fig.5.

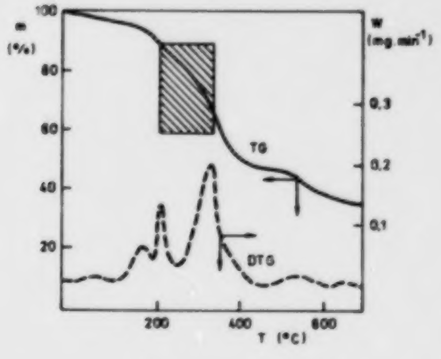

Fig.5 TG, DTG-thermograms of intumescent coating.

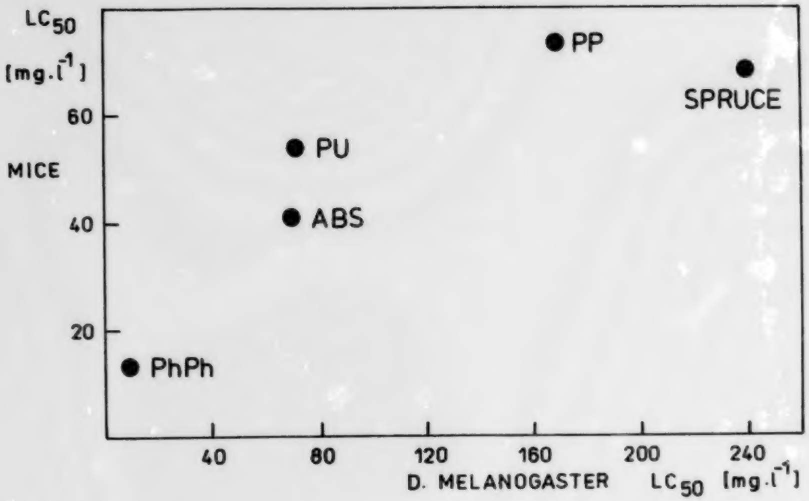

Fig.6 Comparison of toxicity of products of combustion for diferent polymeric materials /Ph-F-cond, ABS copolymer, polyurethans, polyvinylchloride, polypropylene and soft wood /Picea excelsa/.

5 Methods for Research and Testing of Wood Fire Retardants

Numerous experimental techniques and testing methods, which serve to look for the new effective procedures in wood protection against fire, can be divided into some groups according to various aspects [31,46,69]. One of the applied modes of classification is the aspect of the dimension of a test. All methods are divided into three groups:

- methods of fundamental research /very small dimensions of samples/,
- standardized tests /dimensionsand geometry of samples are described/,
- macrotests /dimension are equal with those used in the practice, in definite structures/.

The methods of fundamental research include thermoanalytical techniques /TG, DTG, DTA and DSC/ [13,21-24,33-35], pyrolytic chromatography [35,46] spectral methods /particularly IR and EPR/ [5,8,9]. This group incorporates the methods of chemistry of flame and those of chemistry and physics of high temperatures

[8]. The main purpose of using those techniques consists not only in comparing the efficiency of retardation, but also in elucidating its mechanisms [7,13,21-24,34-43,67,68].

The needs of practice affected the development of fire norms related to the initiating stage of fire, the propagation of fire and completion of the whole process.

Methods for determination of ignition parameters usually include:

- determination of ignition temperatures /some modification of Setchkin test/ [84],
- limited oxygen index /LOI/ determination /some modification of technique developed by Stepnicka and Di Pietro [85].

The combination of thermal analysis and LOI determination technique gives new possibilities for study of ignition of smoldering [41,42]. Another possibilities include measurements of oxygen consumption by samples which are heated at definite mode [44,45,72].

The methods related to the fire-propagation are based on various outgoing criteria [69]:

- weight-loss,
- spreading of flame, charring rate [48,49],
- heat release.

Most of the tests/especialy those based on the weight-loss showed to be unsuitable providing also a confusing informations which were not confirmed in real fires sufficiently [72]. Therefore expensive macrotestsare often used to prove the results of research [46].

6 Trends for Future

In the sphere of protection of wood products against fire one may follow the three pronounced trends which are in agreement with the subject matter of our sessions /S-5.03-04; P-1.09/ [43,63,64,73-82].

6.1 An effect to obtain a more exact knowledge in the process of burning and its retardation is well under way. A search for effective fire retardants will lose its empirical character [43,79,81]. In such a way it will be possible to gain more information on the fire retardants actions; /mechanisms and synergistic effects/ and improve the predicting of fire risks of treated wood products in the particular structures [41].

6.2 The protection against fire will be ensured in accord with additional requirements made upon the stability of products and upon the increase of their resistance to all degradative effects [63-66]. The protection should ensure all product's properties requested in the appropriate sphere of their utilization and prevent the emergence of problems associated with stability of strength properties [63] and dimensional stability [80]. Retardants designed for exterier applications should be made in leach-resistant systems [11,64]. In interier, there must be ensured some hygienic requirements and the retardant must not cause an increased smoke density and toxicity [82]. Morover, the esthetic properties of treated products should also be retained. The new kindsof composites are being developed on the basis of wood and wood components. Their unflamable and fire-resistant treatment will demand a special solution [65,77,78].

6.3 An important trend is demanding the more exact and more perfect testing methods for data-base of computers [83,84]. The norms and standards are significant mainly when they are developed on the international basis /ISO/, allowing to elaborate the internationally valid legislation /for transport, civil engineering, scenic and exhibition facilities, etc./ [70]. As an example of the well thought-out system of norms for the flammability and fire-resistancy of wood products can serve the system developed in France [71].

The computers will permit to evaluate the unflammable and fire-resistant treatments from the complex /also economic/ point of view. An important step will remain to verify the fire-resistant treatments in the practice.

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EFFICIENT PROCESSING FOR QUALITY PRODUCTS

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SUMMARY

The concept of quality is briefly discussed and distinction between structural and aesthetic qualities is made. The grading systems and their importance is treated and the need for development of automated methods is pointed out. Some aspects of efficiency determining factors are discussed and the development under way in several sectors is briefly described. The future demands of the processing plants are outlined. The tendency of diminishing log sizes and lower wood quality is discussed. On the basis of the conditions in Norway a description of how a wood processing plant (sawmill) may be constructed is given. Several of the technical innovations necessary to fully implement the ideas are briefly described.

Keywords: Quality, grading, efficiency, sawmill, innovation.

INTRODUCTION

Prior to a discussion of efficient production for quality products the concept of **quality products** must be defined and described both generally and related to wood products. On this basis the effectiveness of different production systems by which wooden raw material may be transformed to **products** can be judged.

Wood has been a major material for a large number of products and uses to this very day. Up to but a few decades ago wood was virtually without competition. This is no longer so. Today designers and producers of numerous sorts of goods may choose between many materials and combinations of materials. Some of the competing materials are not as good as wood as far as properties go but they still take market shares from wood. Admittedly some display some properties as good as, and even well above, those of the best of woods.

THE QUALITY CONCEPT

The concept of quality has many values, from something descriptive to something related to degree or standard of excellence.

In relation to wood products a product of quality may be defined as one having properties satisfying reasonable demands for the type of product in question. This of course, is in itself not a definition that can be used as a measure of fulfilment.

The acceptable quality standard is for most properties not a constant over time. Materials used in industries must today be more uniform than was earlier tolerated. The beauty concept is changing. Wood characteristics like knots may today not only be accepted but preferred over the knot-free flawless material that was the ideal some decades ago.

Quality Characteristics

One of the important characteristics of a material is its competitivness relative to other materials. The competitivness can be as the price of the material alone or as the final cost of the installed material or product. More and more the cost of the finished product or construction is what is being emphasized. Other factors, like the energy consumption necessary to produce the material or the total energy consumption needed to make the final product or construction, are becoming more and more important.

The most important characteristics of a material, however, is its ability to satisfy the demands for it as a material. In order to judge whether this is the case the actual use and the demands for each particular area of usage must be studied.

If we scrutinize the usage of wood we find three major areas:
- Use as a construction material, i. e. where stiffness and strength of the wood is of importance
- Use as a barrier material, i.e. as exterior cladding and similar use and where the wear properties in many cases are the most important.
- Use as a decorative material, i.e. as interior panelling and the like and where the appearance of the material (its colour and its pattern) is of importance.

In many cases a material is wanted that both has certain constructive qualities as well as decorative qualities. The problem of choosing the right wood species or to select the best suited grade of one species is then to be able to pick out the best possible compromise. If one of the demand areas only is looked for at the time, different wood species may be chosen for each area. Even if we so do, the differences within each species for each of the properties in question vary considerably.

The traditional method for selection of those pieces fulfilling the demands has been to sort out, or grade, among the finished or semi-finished pieces, those satisfying the demands.

Such procedures are common in all countries. The number of sorting or grading systems for each group of demands is very large. The selection systems usually are different for different wood species, although some commercial species of fairly similar properties are sometimes graded together. Examples of this may be the grading of pine and spruce in the Nordic countries, and grading of construction qualities of pine, spruce and fir in northern America into which even aspen may be included in some areas.

Selection or grading systems are found as well within districts as nationally. In international trade they are very important. Much effort has gone and is going into the creation of overnational standards for wood grading. Just now the CEN standards, which will be used in the European trade, are being established. Because wood is used in numerous ways a special grading system for a single sales transaction between one producer and one buyer may often be negotiated.

In addition to grading rules defining the woodmaterial-quality, rules are established regarding dimensions, tolerances, moisture levels, degree of machining defects allowable, etc., etc.. These rules are also plentiful.
For the detection and evaluation of several of these factors implements like moisture meters, tolerance measuring devices, etc., etc., have been developed, while most of the so-called quality grading systems are still based on the vision of human graders.

Quality of Construction Materials

The use of a construction material can be described in objectively measurable terms. The most important strength criteria for wood used in constructions are elasticity (in bending), bending strength and crushing strength perpendicular to the fiber direction. The far largest number of internationally traded wood species used in constructions are softwoods. These are remarkably equal and most of them have an average dry density of around 0.5 g/cm^3 or a little lower. The grade is usually determined by visual inspection and the most important strength reduction criteria are knots (sizes and locations) and annual ring widths (Wood Handbook 1987).

The main strength properties vary widely. The strength properties of much of the construction softwood used are in fact decreasing. This is due to faster growth and smaller logs coming out of second growth forests. Faster growth of softwoods tends to give lower density. Smaller softwood logs contain relatively more juvenile wood, knotty wood material, spiral grain and reaction wood than found in mature and large dimension virgin trees.

Most of the visual grading systems are not very dependable in their ability to distinguish between the different strength categories. Knot sizes and annual ring widths on which the visual grading systems are based are not the best strength determinants. Better are the fiber angles in the material surrounding the knots, as well as the density of the material. These properties are however very difficult to observe in a simple way and hence most visual grading systems are still in use.

The correlation between the modulus of elasticity and the breaking strength (in bending) is for wood fairly good. The so called stress-grading machines are based on this principle. Much effort is going into development of these and of other types of machines that can non-destructively test construction lumber with some accuracy. In addition to stress grading, only proof-loading, which is a way to pick out pieces of inferior strength and thus increase the breaking strength average, has gained any acceptance.

Quality of Non-Construction Materials

A very large part of the wood is not really utilized as far as the strength possibilities go. For each specific use, however, the need to be able to pick out the quality needed is as great as it is for construction lumber. The grading criteria are very often different. In addition to characteristics like knots and such, properties like colour and grain texture may be of importance. A particular feature regarding what may be called aesthetic quality is that it is sometimes linked to the mere price of the material - high price meaning high quality. This sometimes leads to the use of very exotic materials, most likely because they are expensive and therefore indicate that the owner is wealthy and can afford their use. One of the oldest recorded examples will be the use of Lebanon Cedar and Cypress in the temple of Jerusalem (The Bible, any version).

Grading of non-construction materials is so far almost exclusively based on visual grading. The graders try to the best of their ability to distinguish between the different grades defined in more or less specific grading rules. Automated optical scanning systems are underway. Still only a limited number of such devices is in actual use.

EFFICIENT PROCESSING

Efficiency as a concept is not much clearer than the concept of quality. Efficiency of wood industries converting logs into wood pieces for numerous purposes is many faceted. The ability to make a good return on investment is one way to judge efficiency of a wood industry. Another way can be to look at the yield factors - the volumetric yield or the economic yield. Still another judgment of efficiency can be to evaluate to what degree an industry is able to keep up competitivness in the market place.

The abovementioned ways of looking at efficiency and many more are of course interrelated. They are linked because efficiency in one respect may influence the efficiency in a different respect, one way or the other.

Efficient Economy Means High Yield and Quality

One may argue that an efficient economy is a must for all industries. And it certainly is. The reasons are of course first and foremost that the companies in question shall stay alive. But not only that is important. If a business is to prosper and have resources to develop new products and markets it must have a result that is above the mere need for a short time survival!

The economic result of a business is the difference between the income of what the company is selling, what interest it may have on capital or investments in other businesses and the sum of the cost of raw materials, labour, services, and capital. Many studies have been made of what size a wood processing operation should have in order to be profitable. The answer is highly dependent on a number of factors, varying from time to time and from place to place. The most important factor is usually the price of the main product. In many sensitivity studies it has been established that at otherwise equal terms this is the most effective means of changing a company's economic result. In other words: a high product price is often more important than high yield, high volume or high workforce productivity. This does not, of course, mean that production volume and productivity are out of interest, nor cost of labour and capital investments.

For many types of wood industries making commodities like particle boards and such, the sales price is more or less commanded by the market and in those cases the economics of scale seem to be the most important competitive factor.

In a recent study of a sawmill operation in Norway processing 60,000 m^3 of logs a year, making a profit of a meagre 2% on the turn-over, we found the following (Birkeland 1990):

5% reduction in labour costs increased profit to 3.05%

5% increased volume of logs increased profit to 3.67%

5% increased yield of volume increased profit to 5.66%

5% increased sales price increased profit to 6.16%

Turning our eyes to what could be the possible profitable investment in a new sawmill of the same type as above we found that with the current price levels on lumber, logs, labour and equipment in Norway it was not possible to build an economical viable sawmill like that! Under other circumstances, however, it could be a highly profitable investment.

Technical Efficiency

The concept of technical efficiency may need clarification.

similar units, the accuracy with which it is able to function and how it is possible to utilize the volumetric potential in the raw material.

Type and standard of the technical equipment of course determines the technical efficiency. The ability of the crew to make the equipment perform and to use its potential is probably just as important. We have been studying several tecnical efficiency factors in sawmills over the last decades. In Norway it seems that the efficiency in technical productivity has increased considerably, expressed as volume throughput, but that for instance the accuracy has not improved (Tronstad 1989).

With an increasing degree of automation the operators are partly substituted by machinery and automated devices. The fine-tuning of machinery and tooling seems to be lacking in this modernization. The distance between the operators is increased and with that the support the operators can give one another is diminished. Besides giving stress symptoms to the operators this may lead to that production defects go unnoticed for quite a while (Birkeland 1989).

Efficiency Regarding Wood Utilization

The main purpose of a wood processing plant is usually to get the most out of the available raw material. With logs from different forest locations a major problem will be to determine how to start the breaking down of each log in order to get the best quality out of it. The older and larger the logs the more difficult it is to judge the inner quality. Several techniques are used to try to get the best quality out of the logs. Some start by a very thorough external examination, trying to judge by bumps, sweep, ovality and other factors if serious defects may be hidden inside. Other methods combine this with a breakdown pattern starting from the outside and where the operator after each cut judges the quality of the remaining part of the log and how best to break it further down. Devices "looking through" the logs are being employed and a lot of research and development is going on around the world (Birkeland 1989).

Besides qualitative considerations, volumetric efficiency is important. The break down pattern is important and a number of sophisticated systems trying to optimize the volumetric yield are today available. So far all of the commercial programs are based on exterior data and most of them simplify the geometry of the logs to that of a truncated cone or a similar geometrical body. A major problem in many areas is sweep of the logs. This is mostly counteracted by trying to saw along the curve of the log or by pressing it flat during the sawing process.

Log sizes of course are important. The breaking down of a log means to convert something roundish and conical into pieces with rectangular cross-sections. The larger the log the more of the volume can be converted into rectangular pieces. With diminishing log sizes in many parts of the world the volumetric yield of processes using traditional sawing patterns is going down. Much effort is being put into development and research of methods counteracting this tendency. Most attempts aim at cutting thinner wood pieces, with as little sawdust as possible, and glue the thin pieces together. The use of knives are interesting and several developments are underway. A German company (Linck) has recently marketed a machine for slicing thin boards. French and Japanese developments along the same lines have been around for some years already

EFFICIENT PROCESSING FOR QUALITY PRODUCTS

Looking ahead I see a plant for efficient processing for quality products that may be viable in my home territory. The model may be viable elsewhere as well but quite clearly not everywhere. Most of the details needed in this somewhat visionary sawmill of mine is already available. Some details still retain to be developed but in my mind they should be so by the turn of the century, if not before (Birkeland 1988).

As briefly indicated the future demands for the products will be more strict than hitherto. A chief demand will be that they are more uniform than today. The products shall have as high a strength and stiffness as possible, they shall be delivered in practically speaking all dimensions, they are to be graded, sorted, dried and otherwise treated to suit the individual needs of the customers, whether these are individual small volume buyers or large industries. More and more must the products be dimensioned and finished for the final use of the buyer. Last but not least on my list will be that the mills must provide their customers with their orders at much shorter notice than today and preferably just in time (Birkeland 1988).

With this on one hand, and the decreasing log sizes and dwindling of the virgin forests on the other, the processing unit shall be able to deliver what the market demands on the basis of the available raw material, while making a profit! The previous discussion indicated that high product value is one of the most important factors. With this goes that the ability of the processing plant to use the inherent qualities of the logs is very important.
The ability to select the right grade for the right purpose is equally important.

The basic technologies in my vision are not very different from todays. Sawblades are still metal sheets with teeth fixed to the edges. The main difference is that the sawblade bodies are no longer made out of steel. They are made of different alloys with low thermal expansion. Thus many of the sawblade problems are eliminated.

The machinery in the sawmills are of three main types. Bandsaws for the deep cuts, circular saws for the smaller size logs than today. The new generation electronics control the power directly. Electronic indicators supervise all functions and help position tools, fences and such. Decision making is to a large degree done by or helped along by computers calculating the optimal choices and selecting or indicating the best solution. Operators are still the real decision makers in important matters. The operators are few and well educated. They have several functions. They move around more than we are used to seeing today. They are linked together in the sense that they either work in the same room or have electronic channels for sound and pictures at disposal.

Logs are scanned outside for characteristics and geometry of importance for the decision of what the best cutting pattern will be. Internal scanning is done both qualitatively, i.e. identifying the different types of internal characteristics and quantitively, i.e. searching for the ratios and masses of the different characteristics like rot, knots, reaction wood, etc., etc.. The information gathered by the log scanning systems are used both for an inventory control of the log volume in storage and for determining the processing pattern for each log.

The products are largely produced to order but unavoidedly more general products must be produced in order to fully use the potential of each log. The individual pieces are sorted according to customers and/or further treatment. The treatment can be drying, machining, resorting, fingerjointing, laminating, painting or impregnation etc., etc..

END REMARKS

Wood as a material has a tremendous potential if chosen, processed and treated properly. The processing must be efficient in all aspects and the main aim must be to produce a competitive product. The competitors have one advantage in that they usually are fewer and they are large. The only way to cope with this competition is to produce qualities suited for the needs of the customers, be effective and finally: let the world know it. The latter indicates that much remains to be done in the field of public relations, sales promotion or plain marketing!

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EFFICIENT WOOD PROCESSING

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SUMMARY

Three of the main goals for the R&D work in the wood processing area are better utilization of the wood, better product quality and a better working environment. To reach these goals many problems must be solved. Among a lot of R&D tasks I would like to mention the following especially:
- Find methods to decrease the lateral forces on the tooth edge.
- Find methods for active control of the cutting process and the cutting tools.
- Develop more scientific methods for maintenance of the tools.
- Develop better position and feeding equipment.
- Develop methods for slicing thick lumber without uncontrolled splitting.
- Find methods for surface finishing that gives good surface quality, low noise and low dusting.

Keywords: Wood processing, kerf width, surface quality

INTRODUCTION

The total wood resources on the earth are rapidly decreasing due to deforestation and pollution, such as acid rain but also due to the increasing use of wood for wood products and for fuel. Accordingly the relative cost for saw logs have increased during recent years. In many Swedish sawmills the cost for saw logs amounts to about 70 % of the total costs.

However a more serious problem than high log prices is the global shortage of wood resources. This, together with the economical realities mentioned above, makes efficient utilization of wood resources very important.

Utilization of wood resources can be improved in several ways such as by improved wood processing techniques, better break down patterns, better planning and management and by development of completely new processes. The first part of this paper will deal with how we can develop wood processing technology in order to improve utilization of wood resources.

A second problem for the wood industry is the competition from other materials such as steel, aluminium and plastics. In order to compete with these materials the wood industry has to improve both production technology and product quality. Two ways to do that are to reduce the tool wear rate and to improve the surface quality of processed wood products. The second part of this paper will deal with these problems.

The third problem we have to face is the working environment. In Sweden many wood industries have problems hiring enough workers due to the fact that other industries have a better working environment. If we can't improve the working environment in the wood industry we will be unable to compete with other industries. To fully cover this topic is far beyond the scope of this paper, but we have to realise that the working environment issue must always be kept in mind when we are developing new wood processing techniques.

IMPROVED WOOD PROCESSING

Reduction of Kerf Width

In the sawmills approximately every tenth log will be converted to sawdust. As the price difference between sawdust and lumber is very big great R&D efforts have been made in order to reduce the kerf width. The ultimate goal is cutting without producing any sawdust.

To reduce kerf width is not so very difficult but to reduce kerf width and in the same time maintain good measurement accuracy and good surface quality is really a challenge. We have to look at the whole production process from the forest to the end-user product and try to minimize the total waste of wood.

The cutting process.

Wood cutting is an interaction between tool, machine and workpiece. Very much work has been done in order to improve the tools and the machines. Far less work has been done in order to improve the workability of the workpiece. One of the few examples is the steaming of veneer bolts.

Mohan et al (1980) have investigated whether applied voltage changes the force pattern which occurs in wood cutting. This was accomplished by measuring cutting forces in slow speed orthogonal cutting. Cutting forces were measured with voltage applied between tool and workpiece for the case of zero current flow. The voltage level was varied between - 500 V and + 500 V.

Mohan found both from the measurements and some theoretical calculations that the applied voltage of 500 Volts has negligible effect on the mechanical aspects of the chip formation process. Relatively small imposed voltages can however, have large effects on the electrochemical wear phenomena as reported by Kivimaa (1954).

Kimura et al (1984) have tested how heating of wood with microwave energy affects the parallel cutting force and splitting parallel to the grain ahead of the cutting edge. They found that the cutting force when cutting microwave heated water saturated wood was only one-quarter of the force for cutting air-dry wood. The microwave heating did also decrease the splitting ahead of the cutting edge.

Torgovnikov (1982) have used RF-heating to thaw frozen wood in a concentrated zone near the shear-blades. When cross-cutting frozen logs the cutting force was reduced by 30-40 % and the depth of cracks was reduced tenfold.

Ask (1984) has in a US patent described equipment for concentrated heating of the wood near the cutting edges. An electric voltage is applied between adjacent teeth so that a localized heating of the workpiece is obtained at and around the cutting tips, in order to facilitate the cutting, see figure 1. The heating will decrease both the main cutting force and the lateral forces. As the heated zone is very narrow the cutting edges will be forced to follow the heated zone. Another feature in this invention is that the voltage can be varied in such a manner as to prevent or induce non-linear cutting. In this a third pole must be interposed between the cutting edges.

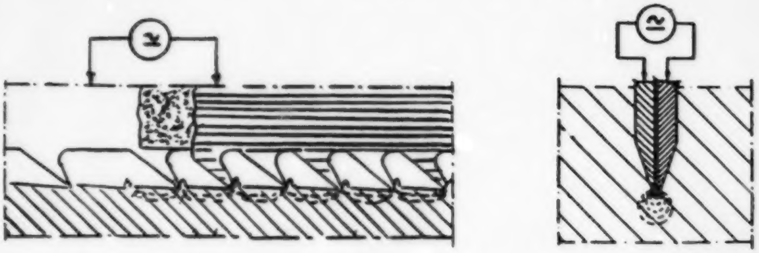

Figure 1. Equipment for local heating of the wood by means of an applied voltage between different parts of a tool comprising at least two cutting edges electrically isolated from each other.

I think that we must increase our efforts to improve the workability of wood, despite the fact that not all of the reported investigations so far have been successful.

Research concerning wood machining processes has during recent years mainly been concentrated on studies of the dynamic stability of tools. This research has led to a reduction in the saw kerf width and an improvement in the accuracy of measurement, and/or to an increase in production capacity. However, this has meant that the saw tooth itself has increasingly become a weak part of the tool.

If you put a lateral force on the edge of a bandsaw tooth approximately half of the total deflexion is due to deflexion of the tooth itself and the other half of the deflection depends on twist and lateral deflexion of the band. The effect of this can be seen in the results from test sawings carried out by Grönlund et al (1978). In this test different band thicknesses were compared regarding the measurment accuracy on the sawn lumber. The tests were designed so all bands with different thicknesses should have the same total stress. This design implied that the thinnest band had the highest static stability. Despite that the thinnest band had the lowest measurement accuracy as can be seen in figure 2. The only explanation we have for this behavior is that it is the rigidity of the tooth itself that is most important when you get

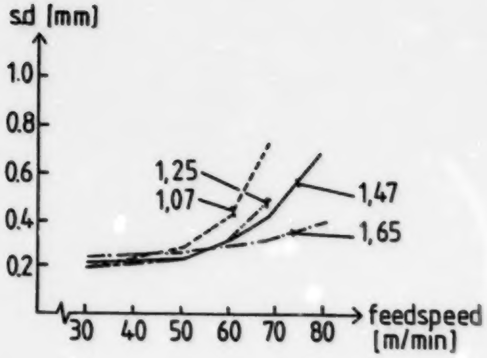

Figure 2. Standard deviation within boards as a function of feed speed for different band thicknesses. Cutting height 150 mm, pitch 35 mm and cutting speed 35 m/sec.

high loads on the teeth.When we exceed the gullet capacity the sawdust causes friction heating and large lateral forces which causes lateral deflexions.

Woskresenskij (1955), Franz (1958) and McKenzie (1961) have all made valuable works for a better understanding of what happens close to the cutting edge. Despite that, much research has to be done before we have a good understanding of the mechanisms involved in chip formation. This is especially true as far as the lateral forces are concerned and how the tools are working when the edges are getting dull.

A step in the right direction has been taken by Krilov (1988). He has applied some of the old theories and developed a very unconventional sawtooth profile, see figure 3. He reports an increase of >32 % in output and 22 % in effective cutting time compared with the best conventional bandsaw blades.

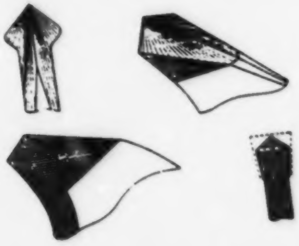

Figure 3: Unconventional sawtooth profile. Krilov (1988).

An even more unconventional idea is presented by Ask (1984). This patent describes a saw unit for wood machining, comprising of two parts, see figure 4. The saw parts are mutually displaceable in the direction of tooth travel and/or in the direction of travel of the object being sawed. By a change in position of the teeth, specific and required effects can be achived. For example, in a circular saw, if a tooth of one group is moved further radially outwards than the tooth of the other group, the former will make a deeper cut and exert a greater influence on the direction of the kerf to the right or the left. If such a position change is made in a proper way, the radially outward teeth will exert a counteracting effect on the forces which emanate from,for example, the inclined texture of the workpiece. The same effect can also be achieved if the teeth of one of the sawgroups are disposed circumferentially closer to the teeth of the other group.

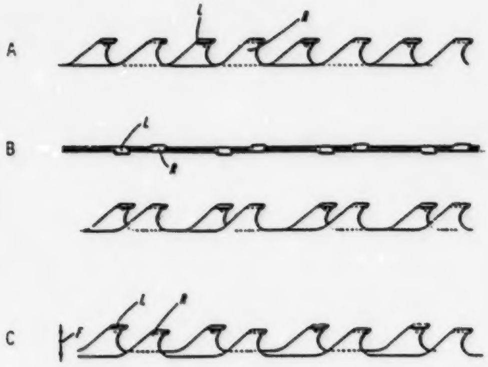

Figure 4. Saw unit comprising two parts. A= The two parts are cutting equal. B= Pitch displacement. C= Feed displacement. L= Left. R= Right.

This leads us into the topic of monitoring and controlling the wood machining process. Much has already been done in this field but I think that even more remains to be done. We are very fast getting better sensors and better computers which means that we have better opportunities than ever to solve difficult problems.

Tanaka et al (1988) and Lemaster (1988) have used acoustic emission (AE) for monitoring the cutting process. Tanaka used the AE signal for on-line control of the feed speed when cross-cutting with a circular saw. With this on-line control Tanaka managed to improve the quality of the cut surfaces.

Lemaster found that the AE count rate decreased when the edges were becoming dull. This decrease reflects the change in the chip formation process with the dulled tool. Lemaster also managed to couple the AE sensor to the moving saw blade. The sensor was able to detect changes in both the feed speed and the cutting speed of a sawing operation.

Circular sawing and band sawing.

A great deal of research has been done during the last 20 years in order to increase understanding of the dynamic behaviour of circular saws and band saws. This research has been very successful, thus improving the measurement accuracy, decreasing the kerf width and lowering the noise from the sawing tools. Despite this rapid improvement of sawing technology I think that much still remains to be done. As I think that many papers will be presented about this topic here I will not discuss the technology of this important and interesting topic anymore in this paper.

The increased understanding of the dynamic behaviour of the sawing tools has showed us that these tools are very complicated high technology products. Consequently these tools ought to be maintained with scientific methods. Today we usually have to rely upon more or less skilful saw filers. In order to improve maintenance we have to introduce methods with which we can measure the condition of the tool and then maintain the tool in a well controlled process. A step in the right direction is described by Berolzheimer (1989) where he shows how the vibrational frequencies of the circular saw blades are measured both before and after tensioning. Another step in the right direction is the development of automatically controlled machines for straightening circular saw blades and band saw blades.

We have been discussing monitoring and controlling of the cutting process itself. Although we can't monitor exactly what is happening in the cutting zone, we have great possibilities of monitoring and controlling the tools. In this way we will get good control over what is happening in the cutting zone. A good example of tool control is presented by Birkeland (1989). In this paper Birke- land describe equipment for on-line tensioning of circular saws with "thermostress", see figure 5. The equipment is manufactured by the Norwegian company Jajod. This equipment have been successfully running in the industry for several years. Today more than 200 units have been delivered. The tension in the saw blade is maintained by having a predetermined temperature difference between the rim of the saw blade and the area close to the saw collar. As can be seen from figure 5 the temperature is measured at two points. If the temperature difference is lower than the set point level the saw blade will be heated close to the collar with an inductive heater. The theoretical foundation for this equipment has been described by Mote et al in several papers (1973, 1981). Dutina (1982) presented an alternative method for thermal tensioning

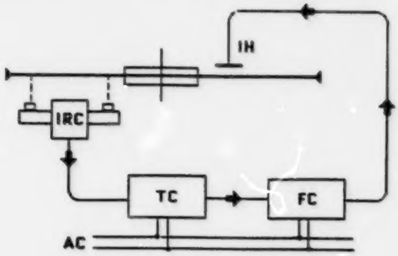

Figure 5: Schematic sketch of Jajods thermostress system. IRC= Infrared camera, TC= Temperature controller, FC= Frequency converter, IH= Inductive heater.

where he controls the temperature difference in the saw blades by changing the temperature of the water that is used as lubricant in the saw guides.

One of the biggest problems in band sawing technology is that some bandsaws have one lateral position during idling and another position during sawing. We have measured displacements up to 1.5 mm. Even if we cannot find out the reason for this behaviour we can perhaps avoid the negative effects of the band saw displacement by using an active control system. Maybe the system presented by Olgiati (1989) and/or the theory presented by Yang (1988) can help us solve this problem. In both systems the displacement of the band is measured by sensors. In Olgiatis system the signals from the sensors are used for controlling the feed speed of the carriage. In Yangs system the signals are used for active control of the band by means of an electromagnet.

In the last 10 years much work have been done in order to find a method for "optimum" positioning and sawing of logs. If you want to find an optimum position for sawing you have to take into account both the irregular outer shape of the log and the inner quality of the log. Johansson et al(1988) have showed that in this case the optimum position is very narrow. If you have errors or play in the positioning equipment it is very easy to loose the whole benefit with a sophisticated "optimization" system. As can be seen from figure 6 the sensitivity for rotation errors is higher if you take into account both the outer shape and inner quality compared with the case where you only take the outer shape into account.

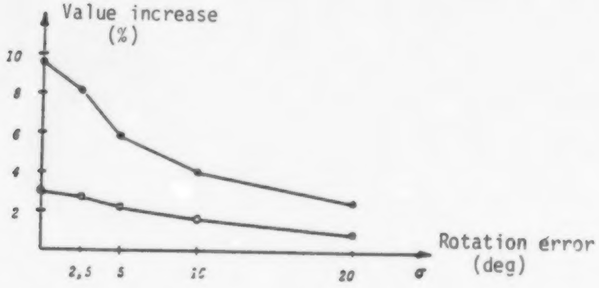

Figure 6. Value increase in % for optimum position in the first saw as a function of the rotation error. Upper curve with knots, lower curve without knots.

From figure 6 it is quite clear that we must also improve our position and feeding equipment if we want to benefit from sophisticated scanning systems. Here I must also mention the lack of good equipment for curve sawing in the second saw. As far as I know all curve saw equipment uses the outer irregular parts of the block for steering the block through the saw machine. These irregularities cause forces that act to displace the tools from the ideal curve. In an ideal system the block should be measured by some scanning system and then moved through the saw machine along the ideal curve.

Frame sawing.

The use of frame saws has decreased rapidly over the last ten years in Sweden. Despite this decrease between 30 to 40 % of the lumber in Sweden is still cut with frame saws. There are many reasons for the decreasing use of frame saws, for instance thick kerfs, bad surfaces due to backsawing, low feed speed, low flexibilty and last but not least lack of technical development. I believe that frame saw technology can be improved so much that frame saws can be a realistic alternative in some cases. Persson (1981) has invented a frame saw where the problem with backsawing can be avoided. In this machine the movable frame is forced to move in a cycloidal curve relative to the workpiece. By avoiding backsawing the thickness of the blade can be reduced considerably, maybe down to 1 mm. Another idea is to replace the movable steel frame with a frame made of plastic composite. With this material the weight of the movable frame can be reduced approximately to a third thus making it possible to increase the cutting speed and feed speed by 70 %.

Alternative cutting methods.

In this group we can find hydraulic cutting, laser cutting and slicing wood with knives. Hydraulic and laser cutting offers a number of advantages over conventional machining processes, as follows : narrow kerfs, ability to cut complicated profiles and produce smooth surfaces. Regarding laser cutting we can furthermore add the following advantages: no sawdust is produced, no tool wear, little noise and no reaction force is exerted on the workpiece. The main disadvantages are low production capacity in terms of cut area per unit of time and relatively high prices for the equipment.

To improve hydraulic cutting we can add something to the water so the density of the liquid jet will be increased. This will however cause increased wear of the nozzle. If laser cutting technology is to come into a more general use, the power economy of the lasers has to be improved very much so that a considerable decrease in price per energyunit is obtained.

I think that hydraulic cutting and laser cutting are and also will be competitive in cases where we can use their ability to cut complicated profiles. One example is cutting of blanks from sawn flitches. In some cases when you can increase the value out of each flitch due to the ability for lasers to make "punch cut" instead of "guillotine cut", which is the method for conventional systems, laser and hydraulic cutting can be very competitive.

Slicing of wood with knives has the big advantage of that no sawdust is produced. The big difficulty is to control the split ahead of the edge. Many researchers have tried to solve the problem with uncontrolled splitting. Among others we can mention Bakiev (1959) who tested vibrating knives and Peters et al (1972) who investigated the effect of different inclination angels relative to the grain. None of these experiments solved the problem completely.

The Linck company in West Germany has perhaps solved the problem. They have recently put a slicing machine on the market. This machine can slice green logs to lumber with a feed speed of 130 m/min. Maximum lumber thickness is 10 -12 mm and maximum slicing height is 160 mm. After slicing the lumber is dried and sanded and then glued to laminated products of desired size. The surface quality of the sliced lumber has been reported to be excellent, Blümer (1990).

Improvement of Surface Quality

"Perfect" surface quality on wood products is essential for successful competition with products made of other materials. It is the area on and in the neighbourhood of the knots that is of vital importance for surface quality, when we are machining solid wood. Many factors influence surface quality. Two of these factors are the cutting method and the sharpness of the tool.

Milling is mostly carried out with rotating cutterheads with the axis approximately parallel to the milled surface. This cutting method causes high impact forces when the knives come in contact with the surface and has unfavorable angle between cutting direction and the grain direction in the knot area. Consequently there is a great deal of damage around the knots. Lycken (1986) has showed that one way of avoiding damage around the knots is to machine the surfaces with sanding instead of with rotating cutterheads.

An alternative method for milling is proposed by Kortylewski et al (1981). They have invented a big conical cutterhead, see figure 7. The angle between the axis of rotation and the machined surface is about 75°. This method gives no cuttermarks, almost no damages around the knots and a very low noise level due to the fact that the number of revolutions per second is very low, according to Porankiewicz (1990).

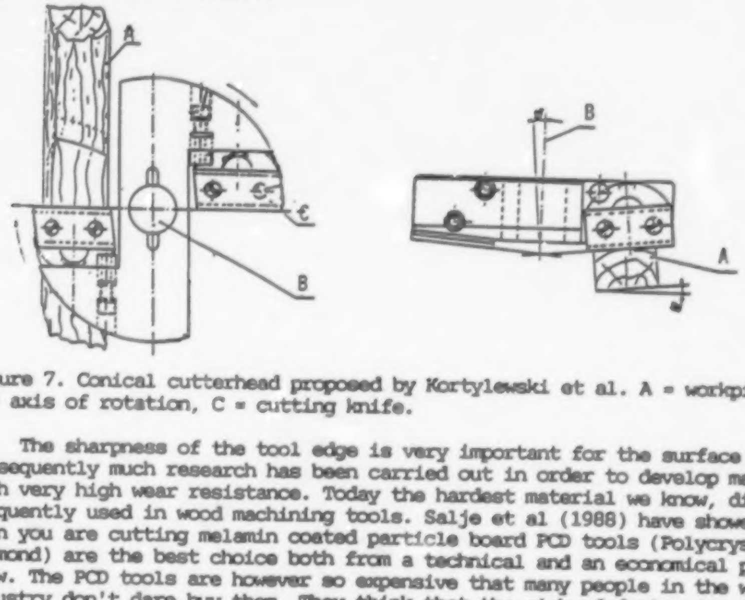

Figure 7. Conical cutterhead proposed by Kortylewski et al. A = workpiece, B = axis of rotation, C = cutting knife.

The sharpness of the tool edge is very important for the surface quality. Consequently much research has been carried out in order to develop materials with very high wear resistance. Today the hardest material we know, diamond, is frequently used in wood machining tools. Salje et al (1988) have showed that when you are cutting melamin coated particle board PCD tools (Polycrystalline diamond) are the best choice both from a technical and an economical point of view. The PCD tools are however so expensive that many people in the wood industry don't dare buy them. They think that the risk of destroying the tools due to contamination in the workpiece is too big.

There are perhaps other alternatives than choosing the hardest material possible. Normally a cutting edge is worn on the clearance side, see figure 8

A. Grundberg (1990) has showed that in some cases the wearing can take place as a pitting on the rake face , see figure 8 B. This pitting had a self-sharpening effect which implied that this specific tool could be used for a very long time between sharpenings.

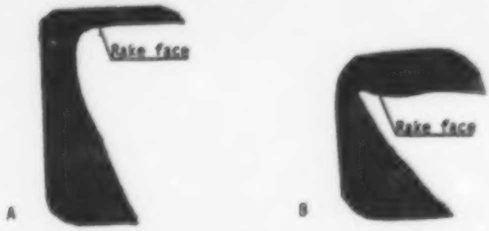

Figure 8. A, Normal wearing profile. B, Edge worn on the rake face.

A good idea is consequently to run the tools with cutting data so we get this selfsharpening effect and/or make the tools so the rake face and the clearance side have different properties. Song et al (1989) have reported the same self-sharpening effect. They had coated a sintered steel substrate with a coating of chromium carbide nickel chromium on the rake face. The coating wore away exposed a sharpened substrate. This resulted in a saw tooth that was almost self-sharpening.

FINAL REMARKS

To cover the whole wood processing area in one short paper is of course impossible. I will however try to summarize which R&D tasks I think are most important as regards the immedite future. The most important R&D tasks are:
- Find methods to decrease the lateral forces on the tooth edge.
- Find methods for active control of the cutting process and the cutting tools.
- Develop more scientific methods for maintenance of the tools.
- Develop better position and feeding equipments.
- Develop methods for slicing thick lumber without uncontrolled splitting.
- Find methods for surface finishing that gives good surface quality, low noise and low dusting.

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DEVELOPMENTAL NEEDS AND POSSIBILITIES IN THE WORKING ENVIRONMENT OF THE WOOD-WORKING INDUSTRY

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GENERAL PREREQUISITES OF DEVELOPMENT

The change in the work environment of the Finnish wood-working industry has been closely connected with the strong technological development in the branch, characteristic of all Scandinavia. The internal factors of the work environment of the most significant fields, such as the saw-mill, board and carpentry industries, as well as the amount of, and changes in, the work-environmental defects, were studied in Finland in the 1970s and the 1980s. The study reflects the problematics of the working environment in a way allowing the priorisation of the future needs for developemnt.

My estimation is that the volume of work-environmental activities will continue at least at the present level also in the 1990s. This is not only due to the work being under way, but due to quite distinct and even rational factors. The mechanical wood-working industry is still very labour-intensive, with some modern saw mills and board factories as exceptions. It is of utmost importance to the industry to maintain the present quality of its work force and to ensure its sufficient quantity. For this to succeed, the industry will have to attend to the needs of development at physically strenuous jobs, for example, where the working conditions may pose a great health hazard. New workers will not seek their way into the branch unless the work-environmental image is maintained at the level of the other industrial branches and especially at the level of that in the new fields of industry and the service sector.

Maintaining the competitiveness of the industry in the international market is a further strong factor. The slogans used talk about an efficient raw-material yield, cut-backs in the costs and an increase in the quality and processing level of the goods. Attaining these goals will require new process and line-production solutions, which in turn will mean higher automation and the resulting changes in the working environment.

The legislative action of the State and the authorities will effect both the needs of development and their scheduling. Amendments in industrial safety legislation may, to some extent, even point the way for the changes.

Ultimately, development will depend on the mental and economic resources that the branch and the individual enterprises have available for investment in the work on the work environment. In general, the matters relating to an improvement in the work environment of the wood-processing industry are not very difficult. There are several alternative solutions to the problems, and thorough and extensive planning based on wide cooperation will make it possible to arrive at economically sound solutions.

REVIEW OF THE PRESENT SITUATION

According to the statistics, the need for development of the work environment in the wood-working industry is above all caused by accident proneness and a relatively high amount of occupational diseases. The accidents have mainly been caused by factors outside the process technology, such as noncompliance with the instructions issued or lack of training as well as carelessness on the way to and back from work. The most significant cause of occupational diseases is noise, a drawback that the workers have been subjected to for decades.

Precise information on the work-environmental situation was obtained from work-milieu mapping, conducted by the speaker in 1978 and 1985. One of the criteria used in the mapping was the subjective evaluation of the subjects on work-environmental drawbacks, which were examined with individual questionnaires shown in Appendix 1.

The opinions prevailing on the work-environmental situation and the possible drawbacks differ in the various sectors of the industry, but also between the different parts of the work force (workers, supervisors, labour-protection personnel, health-care personnel, management). Studied over a long time perspective, the results indicate, in agreement with the statistics, that noise has been and continues to be the most significant drawback in this whole industrial branch (Table 1). In the period under review, from 1978 to 1985, the effects of dust, physical strain and the work rate clearly increased. Related to these, accident proneness would also seem to have increased, which supports the information yielded by the statistics.

The effect of draft has clearly decreased, which is likely to be due to an increase in the quantity and quality of industrial production halls. The effect of chemical substances has also clearly decreased, with the exception of the saw-mill industry, where problems relating to the use of conservation and impregnation agents have been topical.

One would have expected that automation would have increased the mental strain, which, however, in the light of the studies, is so far not to be considered a significant drawback.

The opinions of the different groups involved in industrial safety differ quite significantly from each other. An example of the differences in the viewpoints with regard to the four most significant drawbacks in the saw-mill industry is seen in Table 2. It presents the views on the drawbacks of the industrial-safety delegates representing the workers (TT) and those representing the employees (TM), the occupational health representatives (TE) and the industrial-safety managers (TP) from the years 1978 and 1985.

Table 2 shows that the views of all the groups on the drawbacks have changed in the period under review. A common feature is that dust has "occupied" place 2 or 3 and that draft has been replaced by another drawback in all groups except the worker representatives, TT. Group TT has best maintained its earlier assessment of the drawbacks. In 1978, the group placed dust in place 6, so that the rate of work and dust have only changed places just like draft and physical strain have (places 3 and 4). Groups TE and TP no longer consider low temperature a drawback, and Group TM, for its part, does not experience physical strain as a drawback any longer, but regards mental strain as more significant.

When considering the differences between the various groups, one's attention is drawn by the strong significance placed on physical strain by Group TE, which is further emphasized by their placing the rate of work in place 4. Group TM, on the other hand, emphasizes the rate of work, which may have resulted in the group priorizing mental strain differently from the other groups. Group TM places physical strain in place 5. As the only group, Group TP considers the danger of the work and accident-proneness as significant (place 2), while its place in the other groups was 5/TT, 7/TM and 6/TE. Not all the changes in the views of the different groups in the period under review or the differences in their priorities regarding present-day drawbacks are significant, but they do sufficiently reflect the different positions and different activities of these groups in the organisations. Especially the viewpoint of Group TE differs from the others, because the occupational health representatives look upon the drawbacks from the point of view of the health problems that they see as the most prominent in their patients. Most of the estimations of the other groups are based on the actual industrial environment and on their information and feelings therefrom. This is true both for the saw-mill industry and for the chipboard and carpentry industries.

DEVELOPMENT POSSIBILITIES IN THE 1990S

Traditional means of development

When examining the development possibilities of the work environment in the 1990s, we must, in addition to the drawbacks mentioned above, pay special attention to the technological development in the field and any changes in the work environment resulting therefrom. Development of the work environment can no longer be aimed at an individual drawback or work position. The requirements of the worker with regard to his working environment have changed and he is looking for healthy, comfortable and safe work. Industrial jobs no longer compete for labour only with their wages, but with the whole of the milieu in which the work is performed. Development of the work environment is turning into a continuous planning and development program, which is an indistinguishable part of the strategic operation of an enterprise. A positive work environment creates the prerequisites for an increase in the productibility and profitability of the work. As mentioned above, the means for promoting the safety and healthiness of the work are many. There are means for preventing the harmful effects of noise, dust, chemical substances, etc. The possibilities for the development are purely dependent on the overall development of business enterprises in general and on the economic resources, but above all on the will to remove the defects noticed. This development work may also be influenced by the strength applied in bringing the feedback on these drawbacks to the notice of the decision-makers.

Automation and computer technology

An essential change when compared with earlier development work in the work environment of the wood-working industry will be caused by the adoption of automation and computer technology. Taking these factors into account will be of central importance in the work.

The introduction of automation will not be an unproblematic challenge to the field. Because of the importance of this factor, I will study it from a slightly wider perspective. When automation was first being introduced quite pessimistic views on its effects were voiced. Therefore the utilization of automation, which looks unavoidable, will require purposeful work also for the workers to be able to accept it. A person who has had to give up his job because of automation will find it hard to see any positive aspects in automation. Finding the motivation for retraining may be difficult, no matter how hard or dangerous the person's previous work was. Automation can be compared with the skill of writing in the sense that in spite of negative adjustment effects automation will ultimately enrich the work and life in the work environment both materially and mentally.

In the pioneer country of automation, Japan, which has been considered even an automation enthusiast, they have already had some time to analyse their experiences. Not even there has the acceptance of robots been a mere matter of rationalisation. The interviews conducted have shown that after the first robots were installed, the majority of the workers had a clearly negative opinion about automation. After as long as five years, the number of workers with negative attitudes equalled the number of those whose attitudes were positive. In ten years, the situation was a complete opposite of the starting point. A positive attitude was prevailing. From this we can draw the conclusion that the development of a culture of automation at the work sites will take several years. The first studies conducted in Finland as early as in the 1960s gave similar results. When the share of human work was decreased and the production process was made more automatic, the interest of the workers in their work clearly declined. Machines were controlling human work and not vice versa. When introducing automation, we will also have to attend to the culture of automation, which is actually being conducted extensively within our national basic education system.

The most disturbing threat or force of automation lies in its possibility to replace the human being at nearly all the stages of production. In several industrial fields, automation has already rendered useless the valuable skills acquired by human beings with great effort. This no longer applies to physical work alone. We can already see computer networks replacing the human input through utilisation of the so-called "artificial intelligence", an area referred to as cognitive data processing. Such "expert networks" are at present being used in all areas of economic life.

Intuitively it is clear that while data technology is causing reductions in jobs it is also creating new types of jobs. The prevailing opinion is that based on research, which indicates that new jobs are being created at approximately the same rate as old ones are dissappearing. Another generally recognised threat is connected with the polarisation of work. Work may become very monotonous and require hardly any vocational skills or its may become very specialised work, requiring great skill and expertise shared by a small group of privileged people only. On the basis of studies conducted, this threat also seems, in spite of the negative examples, to be quite premature.

The worst threats have thus proved, even if not totally unfounded, at least less fearsome than was expected. Nevertheless, these results do not allow those working in the development work to adopt an indifferent attitude towards automation, because automation offers a truly positive potential for reform, provided we can harness it correctly.

Taking the most important resource in the work life, the human being, into consideration will be central to the success of the applications of automation.

It is difficult to imagine the wood-working industry moving into the next century without automation and computerisation. The viability of this branch of industry in Finland will, in the long run, largely depend on our ability to find the correct automated solutions.

Future possibilities

In my view, our possibilities of creating more positive work conditions in the wood-working industry in the future are quite promising. We will have to work at the level of attitudes in order to remove the obstacles in the realization of the various measures especially in the decision-making bodies of the enterprises. The information systems will have to be developed, so that the newest research and development results will be extensively available to the plants. The development models with the organisations for industrial safety and health care as catalysts in industrial development projects will have to be made effective use of. The expertise of the workers in the development of work stages involving them is, in most cases, almost indispensable. The compatibility of technological and economic demands with a possibility for the worker to function in the work environment in a manner required by the process, but without risking his health is a goal worth aiming at in all work-environmental development work.

APPENDIX 1

NUMBER THE DRAWBACKS ACCORDING TO THEIR SEVERITY GIVING # 1 TO THE (3) MOST SEVERE ONES, # 2 TO THE NEXT (2) AND # 1 TO THE FOLLOWING ONE. yOU CAN ADD YOUR OWN "DRAWBACKS" IF THEY ARE NOT LISTED HERE.

TYPE OF DRAWBACK	BRANCH OF INDUSTRY		
	SAWMILL	CHIPBOARD	CARPENTRY
PHYSICAL STRAIN	-	-	-
LACK OF SOCIAL FACILITIES	-	-	-
CHEMICAL SUBSTANCES	-	-	-
DRAFT	-	-	-
MENTAL STRAIN	-	-	-
DUST	-	-	-
LIGHTING CONDITIONS	-	-	-
TEMPERATURE, HIGH	-	-	-
TEMPERATURE, LOW	-	-	-
NOISE	-	-	-
LACK OF CONTACTS	-	-	-
HUMIDITY, HIGH	-	-	-
HUMIDITY, LOW	-	-	-
INHERENT DANGER AND ACCIDENT-PRONENESS OF THE WORK	-	-	-
RATE OF WORK	-	-	-
------------	-	-	-
------------	-	-	-
------------	-	-	-
------------	-	-	-
------------	-	-	-

TABLE 1. "MILIEU DRAWBACKS"

1978	1985	1978	1985
THE SAWMILL INDUSTRY		THE CHIPBOARD INDUSTRY	
Noise	Noise	Noise	Noise
Physical strain	Dust	Chemical subst.	Dust
Draft	Chemical subst.	Dust	Physical strain
Low temperature	Physical strain	Draft	Acc.-proneness
Work rate	Work rate	High temperature	Work rate
Acc.-proneness	Acc.-proneness	Work rate	Mental strain
Mental strain	Draft	Physical strain	Draft

1978	1985	1978	1985
CARPENTRY		ALL FIELDS TOGETHER	
Noise	Noise	Noise	Noise
Dust	Dust	Draft	Dust
Chemical subst.	Physical strain	Dust	Physical strain
Draft	Acc.-proneness	Physical strain	Work rate
Acc.-proneness	Work rate	Low temperature	Acc.-proneness
Mental strain	Mental strain	Chemical subst.	Draft
Lack of social facilities	Draft	Work rate	Chemical subst.

TABLE 2.

The four most significant drawbacks in the saw-mill industry according to the groups questioned in 1978 and 1985. TT = worker delegates; TE = Occupational health representatives; TP = industrial-safety managers; TM = work supervisors

TT		TE	
1978	**1985**	**1978**	**1985**
Noise	Noise	Noise	Noise
Work rate	Dust	Draft	Physical strain
Physical strain	Draft	Physical strain	Dust
Draft	Physical strain	Low temperature	Work rate

TP		TM	
1978	**1985**	**1978**	**1985**
Noise	Noise	Draft	Noise
Low temperature	Dust	Noise	Work rate
Draft	Acc.-proneness	Physical strain	Dust
Physical strain	Physical strain	Work rate	Mental strain

COMBINING EXPERT SYSTEMS WITH PROCESS CONTROL IN THE MANUFACTURE OF WOOD PRODUCTS

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SUMMARY

Expert system technology presents substantial potential for improving the product quality and facility productivity of the wood products industry. The issue of combining process control with expert systems is explored in three stages: (1) an interactive, diagnostic expert system installed in a plywood mill, (2) an interactive system installed in a gypsum wallboard facility that uses process monitoring information in its analysis, and (3) a "closed loop" system for a particleboard mill currently being developed.

Keywords: expert system, statistical process control

INTRODUCTION

Expert system technology is an area of artificial intelligence (AI) that is providing the forest products industry with an innovative tool for improving product quality and facility productivity. With an expert system (ES) the less experienced worker in the facility can solve quality and production problems as though he or she were an expert in the area. An example of such a system is a lathe expert system, LES, developed by Massey et al. (1989). LES is in use in two Texas plywood mills and is maintained on the floor at these mills. When a problem arises either with veneer quality or with the mechanics of the lathe itself, the personnel consult LES. This ES guides the plywood mill's worker through an interactive session in which first the cause of the problem is diagnosed, and then detailed instructions on just how to correct the problem are given.

Expert systems are one area within the general discipline of artificial intelligence. The goals of AI are generally held to be two-fold: (1) to make computers more useful to society, and (2) to understand the principles related to intelligence (Winston 1984). In the general area of AI, one of the controversies being addressed currently is, "Are computers capable of intelligent behavior." Searle (1990) presents a case for the negative, while Churchland and Churchland (1990) present a case for the positive. Expert systems relate to this controversy in that the goal of such a system is to encapsulate intelligence about an operation in such a way that the expertise is available to solve a specific problem. The ES houses the knowledge of the expert and presents it in the session in such a way that the system could be argued to be "intelligent" in some sense. But the goal of the expert system is narrowly defined: to decide on corrective action based on expert knowledge. Thus, while the intelligence of the ES is arguable, it is clear that its purpose relates to the first goal of AI: making computers more useful.

The utility of the interactive ES is limited. The knowledge engineer can only build into the system some portion of the total diagnostic process. The way in which the expert approaches many of the problems involves the application of common sense, a form of knowledge that cannot currently be implemented in an ES. After the system is installed, the worker needs to recognize that a problem exists, and then needs to involve himself in an interactive session of unknown duration to fix the problem. Further, after the system has been used a few times, the worker learns the diagnostic paths of system, eventually removing the need for its further use. So, such systems are limited in the total number of problems they can solve and render themselves obsolete over time.

But, such systems can still bring substantial value to the wood products facility. As indicated by Massey et al. (1989), such systems benefit the facility in several ways: (1) they help the facility to systematize its problem solving process, (2) they help prevent the loss of expertise due to retirement and illness, (3) they are an effective training tool for the new employee, and (4) they make expertise more portable between facilities . Mills (1987) points out that a the kind of ES that has the best potential for success is one that focuses on a small, well-defined production area.

We have found that the machines and operations within the wood products facility are very good candidates for expert systems. (1) Each machine center within the facility can be isolated for study. (2) The persons who are sources of expertise are typically accessible for interviews. (3) The reductions in downtime due to the ES can be measured and supplied as the value of an installed system (lathe downtime costs the typical plywood mill about $2,000 per hour). (4) And, the facility typically has a computer system that will house the ES alongside its other applications.

The authors recently reported on an improvement in the effectiveness of interactive expert systems by including photographic images to increase the system's ability to communicate with the user (Massey et al. 1990). Annotated photographs, integrated into the system, clarify terminology, guide the user in assessing a problem's severity, display the distinction between two closely related operating conditions, and pinpoint locations within a complex array of parts in the mill's machinery. The lathe expert system contains many photographs in both the diagnostic portion and the corrective action portion. The only hardware needed to run the system with this enhancement is an IBM-AT compatible microcomputer with one megabyte of internal memory and VGA graphics.

In sum, the interactive expert system is very useful to the facility in diagnosing and repairing problems. But, such systems are inherently limited. They can be made a great deal more valuable to the facility, overcoming many of the inherent weaknesses, through combining the expert system with the process control of the operation. Thus, ES need to evolve from purely interactive to a combination of interactive and process control. They need to retain the value of the interaction between the worker and system, while extending their influence so that they collect information from the process, analyze that information, and finally take corrective action themselves.

This paper presents discussion of the progression of expert system types, from purely interactive to interactive combined with process control. The discussion is based on two installed systems and one other under development. The primary issues to be addressed are: (1) How is on-line process data made a part of the system? (2) How is knowledge related to the process gathered and analyzed for use in the system? And (3) What is the role of the interactive portion of the system after process control has been incorporated into it?

A PURELY INTERACTIVE EXPERT SYSTEM

The lathe expert system (LES) is a purely interactive expert system that was developed and installed in a large corporation's two plywood mills in east Texas. The system was needed because the company's chief lathe engineer was retiring in May of 1988. His knowledge of the repair and maintenance of the lathe needed to be preserved in a readily accessible form. We selected the expert system approach because of the structured approach to the acquisition of his expertise, the logical organization of that expertise in a database, and the user friendliness of available expert system shells. We selected the Personal Consultant Plus[1] shell because it was economical (about $500), easy to use in the development stage, and provided a very user-friendly interface.

LES is a rule-based, Boolean-oriented expert system that recommends corrective action as soon as sufficient information about the problem has been supplied to the system by the user. As a simplified example, in figure 1, a problem with log "spin outs" at the lathe is diagnosed as a sheared gear key. The session begins with the problem of product quality ("initial state") and ends with the recommendation that the gear key be replaced ("goal state"). The utility of such a session to the lathe mechanic is that he is given a systematic "walk-through" approach to any problem, is prompted by the system with words and pictures, and is finally given a course of action to follow to correct the problem. Figure 2 presents one of the annotated drawings from another path in LES, illustrating the extent of information that can be supplied in an ES picture. In still other paths in LES, photographs bring onto the computer screen just what the repairman will see as he goes to work on the lathe.

LES is somewhat limited because it is a purely interactive system. The user first must recognize the existence of a problem, either product quality or mechanical, and then must conduct a session with the expert system. The length of any given session depends on the "depth" of the particular path for the problem under investigation. The "spin out" problem in figure 1 requires only four responses before the system "knows" the problem well enough to recommend that the gear key be replaced. Other problems can require as many as 15 responses.

AN INTERACTIVE SYSTEM THAT USES PROCESS DATA

The logical "next step" in the development of expert systems was to have the system use information about the process that was collected by process monitoring equipment. A large wood products company approached the research group to develop and install an expert system in a gypsum wallboard mill. The system would recommend corrective action for any given product quality problem. The corrective action would need to address all the equipment in the facility. Where LES recommended corrective action for a well-contained piece of equipment, the gypsum wallboard system was to recommend a course of action based on a large number of interrelated machines.

The scope of the problem made the effective use of a simple, interactive ES impractical. The user would spend an inordinate amount of time tracking down various machine readings. Also these readings could be changing so quickly that important changes or trends were not recorded and the ES would not have the process data to account for all the equipment and process parameter interrelationships. But, the mill management still wanted a system that produced corrective action recommendations.

As a result of these considerations, an expert system called GypsumQuest (GQ) was developed with the following characteristics: First, the system contained an interactive diagnostic system, built with PC+. But, an enhancement was added to allow for the complexity of the equipment interactions. Instead of a single action, GQ provides a prioritized list of possible problem causes and associated corrective actions, with the highest priority possible being 100%. At the end of the recommended corrective actions, GQ provides a list of causes that are not likely to be the cause of the problem. GQ provides the supervisor with a list of actions that involve any number of different areas in the production process. Figure 3 provides a sample GQ solution to a problem of wallboard "blistering." The blisters were most likely caused by "bad paper." They were in all likelihood not caused by the "water spray." The percentage numbers are indicators, not true probabilities (Winston 1984).

The major enhancements of GQ over LES were the additions of process monitoring and statistical process control. GQ needed a large amount of data in a timely fashion in order to make the best recommendations. An Allen-Bradley process monitoring system was installed alongside GQ in December, 1988. GQ is designed so that when the supervisor notices a problem, he downloads an appropriate amount of data from the Allen-Bradley system onto diskette. He then transfers the diskette to the computer with GQ on it and initializes GQ. GQ reads in the data and uses as many of the variables as needed, along with information requested from the supervisor, to arrive at the recommendations. Thus, GQ makes use of a large amount of data, minimizing the amount accessed from the supervisor. Currently, there are 200 data monitoring points installed throughout the mill. GQ is designed so that, as new monitoring points are added, the system will use that data in place of requesting it directly from the user.

In order to make the best use of the data, GQ contains a statistical process control (SPC) module. When the data is read in, above, GQ passes control to a program that calculates two-sigma control limits for the available data for each of the 200 monitoring points. Before proceeding with the interactive session, GQ alerts the user to all out-of-control points and allows him to look at the SPC charts for any of the variables monitored. Figure 4 displays a very small, nine-point chart to illustrate this feature. The degree to which a variable is in or out of control is a factor in identifying the best recommendation.

A CLOSED LOOP PROCESS CONTROL EXPERT SYSTEM

The next logical step in the development of facility expert systems is the development of systems that directly monitor the process and then themselves control the process. This is referred to as "closing the loop." The capability of adjusting the process automatically has many obvious advantages (time savings, elimination of human error, etc.), and also a few problems.

With regard to expert systems and process control, the developer needs to address just how combining an expert system in the complete process control framework is any better or even different than conventional process control. Such process control systems are readily available from electronics manufacturing firms such as Allen-Bradley and Fischer-Porter.

The answer to the question, "What do expert systems add," has to be the problem solving reasoning process of the ES. The process control system, alone, uses algorithms to make predetermined adjustments to elements of the process as measured factors float out-of-specification. The expert system, on the other hand, uses the process data to infer corrective action that may not be directly determinable from the process monitoring information, itself.

GQ could not, in its present form, be converted into a fully closed loop system. First, while PC+ does sell an additional module for process control, called "On Line," this module, in its present form, does not interface properly with the normal "Consult" module used to interact with the diagnostic expert system. Second, there is no practical means to convert the prioritized list of corrective actions into a systematic sequence of corrective actions.

Another large wood products company has contracted with the research group to develop a process control expert system for a particleboard mill in east Texas. It is currently in the first stage of development. The elements of this system as it stands provides a framework for discussion of the problems and opportunities for such systems.

The first issue for the closing of the loop is, exactly what portions of the complete process should be controlled by the expert system, and what portions should not. In the particleboard ES, it was decided to select one process variable at a time, and close the loop (the speed of a single conveyor, the temperature of a single dryer zone, etc.).

In order to build a base of knowledge upon which the expert system could base its inferences, an analysis of all process factors needed to be conducted. Data was collected on all the product quality measures, and all the measurable process data for an extended period of time. Statistical analysis was conducted to relate the process measures to the product quality measures.

At the same time, the knowledge related to the expertise of facility personnel was gathered through standard knowledge acquisition interviews. The goal was to bring together the knowledge of the experts into a conventional, interactive, diagnostic expert system.

At present, the system is at the stage where the data is being analyzed and the interactive system is being developed. The system is being written in Clips[3]. A program written in the programming language C will collect the process monitoring information. When out-of-control measures are detected, the program will "wake up" the expert system. The expert system will use the process information and, if needed, information from mill personnel to determine factors in the process that need to be adjusted. The expert system will then pass control back to the program which will make the adjustments to the system recommended by the expert system.

The "principal reason for using a real time expert system is to reduce the cognitive load on users or to enable them to increase their productivity without the cognitive load on them increasing" (Turner, 1986). Process control expert systems fit into this category. An operator in a complex manufacturing environment is dealing with any number of important parameters. These parameters may be controlled manually by the operator or automatically by a computerized process control system. Laffey et al. (1988) cite an oil platform operator, dealing with 500 analog and 2500 digital signals, as an example of a considerable cognitive load. Real time expert systems have been developed to deal with some of these complex manufacturing environments.

CONCLUSIONS

From our research in the area of expert systems, the following conclusions can be drawn.

1. Interactive, diagnostic expert systems have a great deal of utility in themselves, even though they are limited in the operating environment of wood processing.

2. Incorporating process monitoring with the conventional knowledge of the expert system has the advantage of not requiring the user to have a large amount of quantitative data about the operation at his fingertips.

3. Not closing the process control loop has the advantage of not taking the human out of the process control loop. The mill worker maintains the "final say" over what changes are to be made to the process.

4. Last, the closed loop process control expert system represents a significant advance over the conventional process control system. But, the installation needs to be taken slowly and carefully, since the "final say" for each control variable is taken out of the hands of the human.

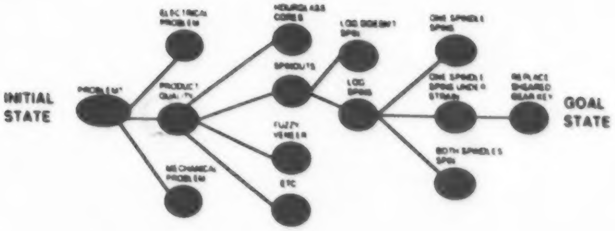
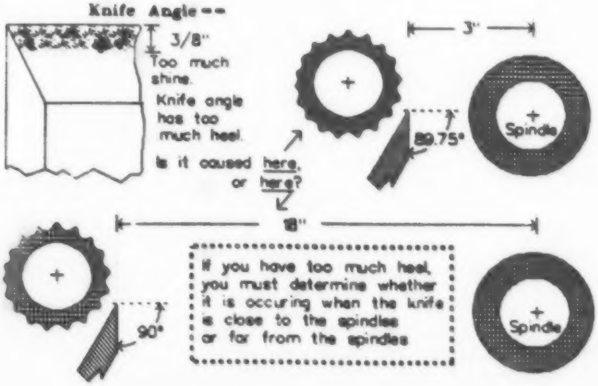
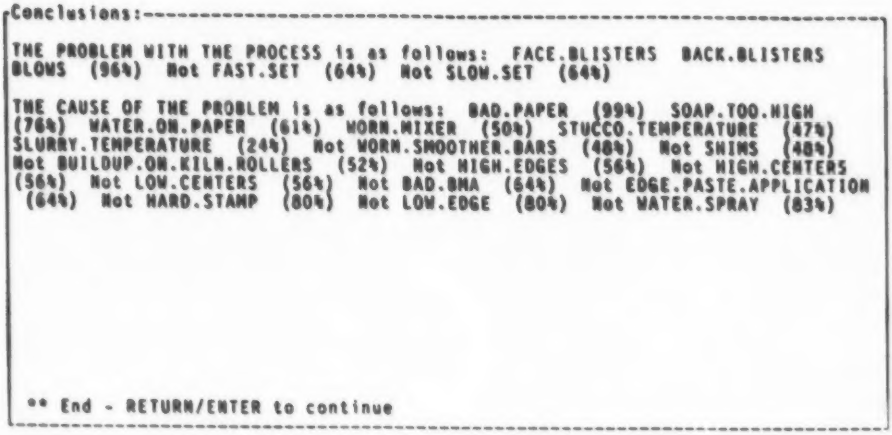

INITIAL STATE
PROBLEM?
ELECTRICAL PROBLEM
PRODUCT QUALITY
MECHANICAL PROBLEM
HOURGLASS CORES
SPINOUTS
FUZZY VENEER
ETC
LOG DOESN'T SPIN
LOG SPINS
ONE SPINDLE SPINS
ONE SPINDLE SPINS UNDER STRAIN
BOTH SPINDLES SPIN
REPLACE SHEARED GEAR KEY
GOAL STATE

Figure 1. A search path for LES illustrates the logic of the session for excessive lathe spin-outs.


Knife Angle --
3/8"
Too much shine.
Knife angle has too much heel.
Is it caused here, or here?
3"
89.75°
Spindle
18"
90°
Spindle

If you have too much heel, you must determine whether it is occuring when the knife is close to the spindles or far from the spindles

Figure 2. Images and drawings in the expert system are used to supplement text descriptions.



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Conclusions:

THE PROBLEM WITH THE PROCESS is as follows:  FACE.BLISTERS  BACK.BLISTERS
BLOWS  (96%)  Not FAST.SET  (64%)  Not SLOW.SET  (64%)

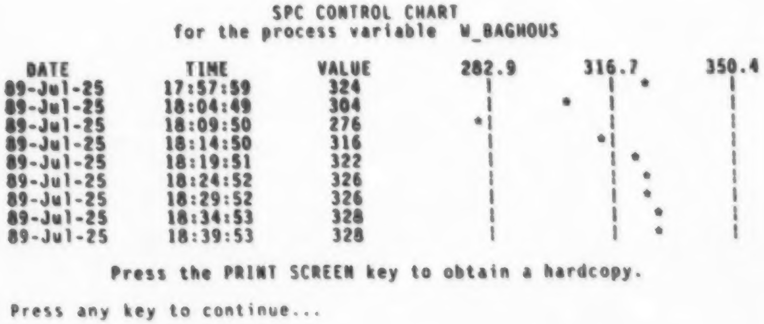
THE CAUSE OF THE PROBLEM is as follows:  BAD.PAPER  (99%)  SOAP.TOO.HIGH
(76%)  WATER.ON.PAPER  (61%)  WORN.MIXER  (50%)  STUCCO.TEMPERATURE  (47%)
SLURRY.TEMPERATURE  (24%)  Not WORN.SMOOTHER.BARS  (48%)  Not SHIMS  (48%)
Not BUILDUP.ON.KILN.ROLLERS  (52%)  Not HIGH.EDGES  (56%)  Not HIGH.CENTERS
(56%)  Not LOW.CENTERS  (56%)  Not BAD.BMA  (64%)  Not EDGE.PASTE.APPLICATION
 (64%)  Not HARD.STAMP  (80%)  Not LOW.EDGE  (80%)  Not WATER.SPRAY  (83%)





 ** End - RETURN/ENTER to continue
```

Figure 3. GypsumQuest provides the user with a prioritized list of probable causes of the product quality problem.



```
                         SPC CONTROL CHART
                 for the process variable  W_BAGHOUS

  DATE            TIME        VALUE         282.9      316.7      350.4
89-Jul-25       17:57:59       324            |          |  *       |
89-Jul-25       18:04:49       304            |      *   |          |
89-Jul-25       18:09:50       276           *|          |          |
89-Jul-25       18:14:50       316            |         *|          |
89-Jul-25       18:19:51       322            |          | *        |
89-Jul-25       18:24:52       326            |          |  *       |
89-Jul-25       18:29:52       326            |          |  *       |
89-Jul-25       18:34:53       328            |          |   *      |
89-Jul-25       18:39:53       328            |          |   *      |

              Press the PRINT SCREEN key to obtain a hardcopy.

Press any key to continue...
```

Figure 4. GypsumQuest analyzes the process data, using the results to identify the best corrective action.

FOOTNOTES

[1] Personal Consultant Plus (PC+), Texas Instruments, Inc., P.O. Box 2909, Austin, Texas 78769.

[2] CLIPS was created by the Artificial Intelligence Section of the Mission Planning and Analysis Division at NASA's Johnson Space Center.

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FUTURE SAWNWOOD DRYING IN AUSTRALIA

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SUMMARY

Plantation softwood will soon overtake native hardwood as the major sawnwood resource in Australia. Virtually all plantation softwood and an increasing proportion of native hardwood sawnwood is dried. This situation is expected to continue.

Drying of sawnwood from the major sources of supply - native hardwood, plantation softwood, native softwood, and imported sawnwood - is discussed. The paper concentrates on current drying practices, particularly as they result from recent research and development, areas requiring future research, and projected developments in commercial drying practices.

Keywords: drying, kiln drying, seasoning, sawnwood.

INTRODUCTION

Projections of future sawnwood consumption provide a basis for estimating future wood drying requirements. Sawnwood consumption exceeds domestic supply, with the difference provided by net imports which will decrease as Australia approaches self-sufficiency early next century. Consumption for 1971 to 1988, with the contributions of the main sources of domestic supply, is shown in Fig. 1, which also shows the trends of projected domestic supply to 2020.

The main sources of sawnwood are -

Native hardwood (broadleaved) - mostly eucalypts and related genera. Production is decreasing as the resource changes from mature old-growth to regrowth forests, but will increase substantially in the second half of next century as the regrowth forests mature. An increasing proportion will be used in dried products.

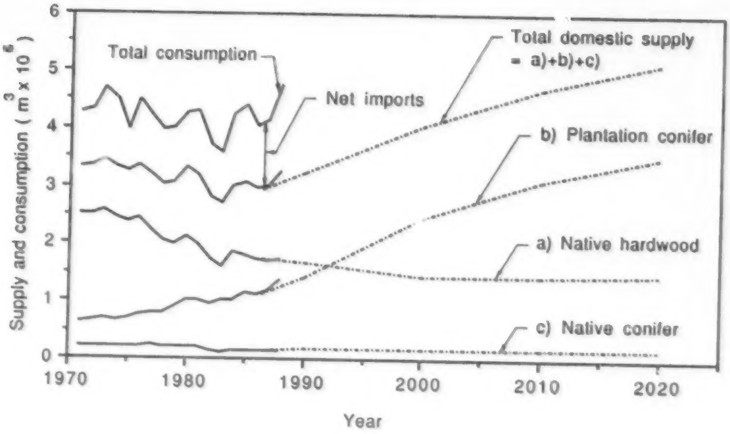

Fig. 1. Consumption, 1971 to 1988, and projected future domestic supply of sawnwood in Australia[1].

Plantation softwood (conifer) - mainly exotic *Pinus* spp., particularly radiata pine (*P. radiata*), but with a significant quantity of native hoop pine (*Araucaria cunninghamii*). This is the principal source of the increasing domestic supply. The sawnwood is normally dried.

Native softwood - the most important is cypress pine (*Callitris* spp. - mainly *C. columellaris*). Supplies are expected to remain relatively constant, but an increasing proportion will be dried.

Imported sawnwood - principally softwood from the west coast of North America, radiata pine from New Zealand, and hardwood from Malaysia. Only a small proportion is dried in Australia.

The drying of sawnwood from each of these sources is considered separately below. Discussion is confined to the drying of solid sawnwood in Australia, with particular attention to current and future research needs and commercial developments.

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[1] Consumption data: sawnwood supply (excluding railway sleepers) - Timber Supply Review, Aust. Bureau Agricultural & Resource Economics, Canberra.
Projected future domestic supply: consumption data for year ended 30 June 1987 extrapolated in the ratios of (projected sawlog availability)/(removals 1986/87), p. 38, Australian Forest Resources - Present Areas and Estimates of Future Availability of Wood, Aust. Forestry Council, Canberra, Feb. 1989.

NATIVE HARDWOOD

Resource

The mature forest resource is nearing the end of its first harvesting cycle and is being replaced by regrowth forest of similar species composition, with a minor contribution from plantations of selected species. The most important hardwood forest groups (types and locations as in FORWOOD 1974, which lists the major species) are -

> Moist eucalypt (Queensland (Q) and New South Wales (NSW)), plus spotted gum (Q and NSW) and some stringybark (northern NSW) and dry eucalypt (Q and NSW). Most are medium- to high-density species that do not collapse appreciably during drying.
>
> Ash (Victoria (V), Tasmania (T) and NSW) and silvertop (V and NSW), with associated stringybark (V and southern NSW) and mixed eucalypt (T). Most are low- to medium-density species that collapse significantly.
>
> Karri and jarrah (Western Australia) - medium- to high-density species that do not collapse appreciably.

Most Tasmanian ash sawnwood is dried for appearance and structural products, but the bulk of Australia's hardwood production traditionally has been used as green structural timber, with only a small amount used in dried products. This situation is changing, and an increasing proportion is being dried for both structural and high-value appearance products. This trend is expected to continue and, together with the change from mature to regrowth sawlog resource, is the major challenge facing the native hardwood industry.

Drying Characteristics

The drying characteristics of wood from both mature and regrowth or plantation eucalypts were discussed by Campbell and Hartley (1978). The most important forms of drying degrade are surface checking, internal checking, and the effects of collapse.

Most species have a marked tendency to check on back-sawn surfaces early in drying. Checking is caused by high drying stresses, may be aggravated by collapse, and is worse in thick material than thin. It can be minimised by slow, controlled early drying, in very mild conditions.

Radial internal checking is likely to occur later in drying unless the wood temperature is kept below a threshold value until the moisture content (MC) throughout is below the fibre saturation point (FSP). Reported threshold temperatures range from 25 to 40°C for collapse-susceptible ash to 50 to 55°C for regrowth blackbutt (*Eucalyptus pilularis*) (Alexiou 1989).

Collapse and its recovery by reconditioning were reviewed by Kauman (1964). It is likely to become more significant as regrowth and plantation grown material replaces the old growth, due to the generally lower mean density of the wood of the younger trees, although little difference in density has been found in jarrah (*Eucalyptus marginata*) and karri (*E. diversicolor*). The smaller ray and poor size in the wood produced in the first 20 years of growth may also be a contributing factor.

Honeycombing, caused by collapse in earlywood, tends to be most severe in back-sawn material, due to the greater restraint from latewood and higher drying stresses in the tangential direction. A contributing factor is large differences in density (and strength) between earlywood and latewood. Collapse in undamaged fibres close to the surface can also initiate or contribute to surface checking (Wilkins and Wilkes 1987).

Drying Requirements

There are no major problems in drying hardwood for structural purposes with degrade within specified limits. However, surface checking may reduce its acceptance for 'appearance' structural grades and internal checking must be limited. Careful early drying may be necessary to prevent unacceptable degrade in some cases, e.g. regrowth ash. Drying is slower and costs are higher than for plantation softwoods. This reduces the advantage provided by the smaller sizes required in structural applications.

Drying appearance grade material is more difficult, particularly in thicker sizes. One method of minimising degrade has been to quarter-saw. This is normal practice with ash, mainly in Tasmania, but is becoming less practicable due to decreasing average log size and the presence of wood defects. Back-sawing is preferred for convenience and greater sawn recovery. It also provides a more attractive figure for appearance products.

The major problem in hardwood drying is to develop economical ways of drying appearance grade back-sawn timber, free of degrade, in both board and thicker sizes. This is the object of much topical research and development (R & D). Related studies have aimed at developing accelerated schedules for kiln drying structural back-sawn timber from green (Alexiou 1989). The knowledge gained from this work is providing a better understanding of the mechanisms involved in drying and the development of degrade in a broad range of wood drying situations.

Research Studies and Modelling

Schaffner's (1981) investigation of drying stress and surface checking in back-sawn ash led to the development of a surface coating system (Ralph *et al.* 1984) to reduce moisture gradients near the wood surface and reduce or eliminate surface checking. Schaffner's analysis was developed by Oliver (1986) into a one-dimensional model of drying from the surface of wide boards under constant conditions. The model is the basis of a computer program called 'DRYWOOD' (Mills *et al.* 1987).

'DRYWOOD' includes strain components due to mechano-sorptive and mechanical creep, as well as unconfined shrinkage and instantaneous strain due to stress. Its value for predicting checking is limited by the assumptions used and lack of data about many of the factors involved. However, it is a valuable tool for demonstrating the effects of the early drying conditions on stress and check development. It also indicates areas where research is required to improve the understanding and modelling of the processes involved, particularly -

Effects of collapse.

Effects of temperature and MC on the effective diffusion coefficient.

Relationships between the air flow over the surface, wood surface temperature and MC, and heat and mass transfer between air and wood.

Mechano-sorptive and mechanical creep perpendicular to the grain, in both tension and compression, including recovery under conditions of stress reversal, and the effects of temperature.

Some studies have been made of the visco-elastic properties of hardwoods perpendicular to the grain (Alexiou *et al.* 1989, Schaffner 1981, Kippo 1987), and Wu (1989) has investigated boundary layer flow, heat and mass transfer and temperature difference at the surface of the drying wood, and heat conduction within the wood. More research is required in all these areas.

Other R & D programs are investigating non-destructive methods for measuring MC early in drying using ultrasonics, and moisture distribution in sample boards using x-ray/gamma ray densitrometry.

Humidity cycling early in drying also requires research. Reports indicate that it re-establishes moisture flow after marked reductions in drying rate in jarrah with no increase in checking, and it may also be a way of using mechano-sorptive creep to reduce drying stress. However, opinions are divided, as it may deepen existing checks and reduce tensile strength perpendicular to the grain.

Commercial Drying

Drying methods for appearance products are more critical and more costly than for structural timber. Freshly sawn wood must be selected and sorted for the intended product and drying process, which may be different for back- and quarter-sawn material. The selection should ideally extend to the sawlogs.

Traditional practice for early drying from green to below FSP has been to air dry. Alternatives, mainly used where air drying is too slow and costly, are pre-driers (Brennan *et al.* 1966) or, more recently, progressive driers (Fricke 1983, Lembke 1984). Air drying is generally satisfactory for structural products, but is often too severe for more critical requirements.

Various approaches are used for protecting green timber from exposure to severe conditions, and providing the mild early drying necessary for preventing degrade. They have been used in trials and are being adopted in general commercial practice. The particular approaches taken are chosen to suit the drying operation, and may include -

Enclosed, controlled environments at the sawmill outfeed and stack construction area.

Wrapping packs of green sawn timber to prevent drying before stacking.

Surface coating of thick, high-value timber with a semi-permeable polyvinyl chloride film attached with a polyvinyl acetate adhesive (Ralph *et al.* 1984).

Shrouding stacks with polyethylene sheet, which is removed when the critical early drying period has passed.

Open-sided air drying sheds that can be baffled with shade cloth to reduce air circulation.

Enclosed holding, or 'curing' sheds for initial drying. They are generally without forced air circulation, but may have evaporative coolers to lower the temperature and raise the humidity.

Pre-driers - normally operated with closely controlled fairly constant equilibrium moisture content (EMC) conditions throughout.

Progressive driers - which have the advantage of the evaporative cooling effect giving low temperature, high EMC conditions at the green end, with the conditions becoming progressively more severe along the drier. However, they lack the flexibility necessary for many operations as they require a regular supply of similar green material.

Conventional kilns - usually low cost, operating at closely controlled, low temperature conditions during early drying.

High Temperature Final Drying

Temperatures limited only by the kiln capacity (c. 100°C) accelerate the final drying of ash in conventional kilns without increasing degrade (Christensen 1985). Similar results have been obtained with jarrah and blackbutt and 'high-temperature' final drying has become normal practice in some plants. Less conclusive results have been obtained in trials with some other higher density species, possibly due to wide variation in initial MC.

It appears that many hardwood species will tolerate high final drying temperatures (120°C or more) without degrade, provided the MC throughout is below FSP. These conditions are likely to cause severe internal checking at higher MC's. They may also lead to large moisture gradients in the dried timber, and make stress relieving and/or MC equalising by final high humidity treatments less effective. Further R & D is necessary to determine the method's limitations, as it is likely to find increasing commercial acceptance.

Special Drying Methods

Vacuum drying

Trials have been conducted into drying native hardwoods in commercial vacuum drying systems, mostly using radio-frequency heating. The results have not been satisfactory, with drying slower than claimed for 'equivalent' northern hemisphere hardwoods, and unacceptable degrade. The process may have application for high-value thick material, but suitable schedules have yet to be established.

Low-temperature vacuum drying, with wood temperatures not exceeding c. 40°C early in drying, could be an alternative, particularly for temperature sensitive species of the ash group. Considerable development would be required, as appropriate systems are not currently available.

Drying thin boards

The problem of degrade can be reduced by drying in thin sections. Faster, more severe drying conditions can be used, at least for most non-collapsing species. An economical continuous drier, similar to a veneer drier, may be practicable.

The dried boards can be glued together to make the desired final sizes, allowing appearance grade material to be selectively included. This process has been investigated for producing high-value appearance products from jarrah and could be applied to other species.

PLANTATION SOFTWOOD

Resource

Radiata pine is the major plantation softwood in Australia and is grown in New South Wales, Victoria, South Australia and Tasmania. Hoop pine, slash pine (*Pinus elliottii*) and Caribbean pine (*P. caribaea*) are grown mainly in Queensland and some maritime pine (*P. pinaster*) and radiata pine is grown in Western Austrlia.

The projection in Fig. 1 for sawn timber from plantation softwood shows increases of about 70, 120 and 150% above the 1990 situation over the next 10, 20 and 30 years respectively. This reflects the rapid increase in establishment of softwood plantations in Australia since the late 1960's. Planting began in a limited way about 60 to 70 years ago and it was not until the mid 1930's, and again post-World War II, that areas planted per year became significant. However, the main impetus came in 1967 with the Softwood Forestry Agreement when it was realised that Australia needed a much larger plantation estate if it was to aspire to self-sufficiency in timber by the year 2000. Under this agreement, funding assistance was provided by the Federal Government to the various State Forest Services for plantation establishment over a 16-year period. The rate of new establishment has declined slightly over the past five years but increased log production is already apparent. In addition, the ratio of final crop stems to lower volume thinnings is also improving, as more stands reach rotation age. At this stage, it appears that net self-sufficiency in sawn timber will be achieved by 2020 and that the sawlog volume of plantation softwoods will equal that of the native hardwoods by 1992.

Development of High Temperature Drying

During the early days of plantation forestry, most of the sawnwood from thinnings was used in low value products, such as fruit cases and boards for covered flooring, etc. The presence of a central core of twist-prone, juvenile wood was well recognised. Producing straight, stable framing sizes from these thinnings, using conventional low temperature kiln drying or air drying was almost impossible and Kloot and Page (1959) recommended that scantlings from radiata pine be produced only from the timber outside the central 100 mm core.

Work in the USA on high temperature drying of *Pinus* species in structural sizes by Kimball and Lowery (1967) on lodgepole pine (*P. contorta*) and by Koch (1969, 1971) on southern yellow pine, stimulated the development of high temperature drying techniques for Australian requirements. Crook (spring) appeared to be the major problem in the USA but, in Australia, it was twist.

The first high temperature drying in Australia on plantation softwoods was done on slash pine studs (D.K. Gough 1970, unpublished report). The techniques used were optimised by Christensen and Gough (reported 1975). At the same time, Mackay and Rumball (1971) undertook similar work on radiata pine and Gough (1973) reported work on hoop pine.

The Australian technique of the early 1970's used a simple batch kiln, modified to provide high air flow through the stack and high temperature, with rapid heating. Recommended drying parameters were -

Dry bulb temperature - 120°C. Wet bulb temperature - 70°C.

Air flow - 5 m/sec. through the stack. 2-hourly fan reversal.

Sticker thickness - 29 mm. Sticker spacing - 760 mm. Stack width - 1.2 m.

Stack restraint - concrete slabs giving about 980 kg/m^2 of stack area.

Pre-steaming - 4 hours. Post-steaming stress relief - 4 hours.

Restraint maintenance for 24 hours after final steaming.

By applying the above, it was possible to dry 50 mm timber from green in less than 24 hours and to recover at least 90% of pieces within acceptable limits of twist, spring and bow from timber which, until then, could barely be used for framing at all. High temperature drying was found also to improve stability under changing EMC conditions and, because of the limited time the timber itself was at temperatures exceeding 100°C, there was no appreciable loss of strength.

High temperature drying of plantation grown softwoods was a most successful and timely development, coming as it did when supplies from the native hardwood resource were starting to decline and when the volume of pine thinnings was expanding rapidly.

In the years since the above parameters were developed, a major proportion of all sawn material from softwood plantations in Australia and in other countries, such as New Zealand, South Africa and Chile, is seasoned under high temperature conditions. As the proportion of outer, more mature wood increases, the need to prevent drying distortion reduces but high temperature drying is still used because it also reduces drying time and energy costs. The only area where high temperature drying is not successful is in the re-drying of timber treated with water-borne preservative. Permeability becomes severely reduced, high moisture gradients develop, long drying times are required and severe internal checking, embrittlement and strength loss develop.

Considerable design work has been done on a high volume continuous drying unit by Christensen and Northway (1982) to run at up to 200°C and, although this unit has great potential, it has yet to be accepted by industry. Apart from this possibility, the future for high temperature drying of plantation softwood is expected to lie in the optimisation of design and operating parameters for batch kilns. Mathematical modelling to develop optimum parameters would be ideal but, as yet, insufficient work has been done.

Present Softwood Drying

Almost all plantation softwood is now dried using high temperature conditions. In some cases, boards 25 mm and less may be air dried and timber thicker than 50 mm may be dried at low temperatures, sometimes in dehumidifier kilns, to avoid the incidence of internal checking. High temperature drying of framing sizes, however, is almost universally applied, because high temperature drying in totally restrained stacks is the only economical way to ensure that a straight stable product will be produced from timber that has a high probability of containing juvenile wood.

Alterations made to the originally determined parameters listed above have often been based on empirical determination and have resulted in the following -

Dry bulb temperature - 150°C has been used. Higher temperatures reduce drying times but 130 to 140°C seem to have general acceptance.

Wet bulb temperature - wet bulb control is not critical and 70°C, which gives a good result, can be achieved with the vents open.

Air flow - increased temperatures require increased air flow. 140°C requires 7 m/s through the stack, at least, in the early part of drying. Some installations are using two-speed fan motors to reduce power consumption in the later stages of drying when the rate of evaporation has slowed. Fan reversal times of 2 hours are still commonly used.

Sticker thickness - some operations use stickers about 20 mm thick and claim good results but a minimum of 25 mm is recommended.

Sticker spacing - this varies from 450 to 750 mm.

Stack width - radiata pine is commonly dried in 1.8 m stacks and sometimes 2.4 m. Slash pine and hoop pine appear to have lower permeability and 1.2 m wide stacks are still generally used, although 1.8 m wide is used at one installation.

Stack restraint - various alternatives to concrete slabs have been examined. Slabs do have some disadvantages, yet they remain a simple, cheap and effective system to use. The most acceptable and effective weight appears to be a reinforced concrete slab about 400 mm thick, giving a top loading of around 1000 kg/m^2 of stack area for 50 mm thick timber. Stack weights less than this (700 kg/m^2) have been used successfully for 38 mm thickness.

Pre-steaming - although pre-steaming was used in the early developments, Hillis and Rozsa (1978) confirmed that heating wood while it was still wet caused plasticisation of the lignin and hemicellulose constituents and reduced the incidence of distortion, especially twist. It is often advised that pre-steaming be undertaken in a separate chamber but good results can be obtained in the kiln by closing the vents and injecting live steam to accelerate heating.

Post-steaming - this is best achieved in a separate chamber and consists of a high humidity treatment, i.e. steam injected to achieve about 90°C for four hours to relieve drying stresses and reduce moisture gradients. Improved long-term stability is achieved by kiln drying to a target of 8 to 9% MC and then steaming to obtain a final MC of about 10 to 11%.

24 hour maintenance of stack restraint - experience has shown that restraint must be left on after drying, but it can be lifted after about 12 hours.

Monitoring of moisture content was done initially using embedded electrodes connected to an external moisture meter. Using six electrode pairs per charge, it was generally possible to conclude drying when the highest meter reading had reached 23%. The internal temperature in the wood, obtained with embedded thermocouples, has also been used, drying being terminated as the lowest reading rose above 100°C. The most common indicator now is time based on experience, in combination with the temperature drop across the load. This has limitations as it is subject to changes in the density and MC of the timber, and to alterations in the kiln operating conditions. To help overcome the problem, Miller (1989) has produced a kiln monitoring system which uses measurements of temperature, EMC and total energy into the system to indicate drying progress. This has been incorporated in kiln supervisory software known as 'DRYSPEC' which includes a library of kiln schedules and alarm sets, etc. It is expected that computerised systems such as these will be used much more in future.

Another recent development (A.M. McNaught 1989, unpublished report) has reduced the incidence of internal checking and is expected to be of value for thick sections, particularly where such sizes are to be used in furniture components. It involves the use of a separate steaming treatment when the core of the timber is still above FSP. It is in this area that the mechano-sorptive theory being developed for hardwood drying is likely to have application in high temperature softwood drying.

Future Softwood Drying

As mentioned earlier, it is possible that the already designed, continuous high temperature dryer could be built, but it is expected that batch kilns will continue to be installed for some time.

Future drying of plantation softwoods is expected to see an improvement in moisture distribution within individual pieces and within complete kiln charges. This will be possible with the application of optimised kiln design and kiln operation, involving electronic monitoring and decision making. Faster drying may be possible but, at the drying rates being achieved in relatively simple batch kilns (8 hours' drying time for 38 mm radiata pine at 150°C), this is not considered to be of great importance.

A satisfactory final MC is important in order to achieve trouble-free, long-term stability. One development being used already to some extent is the in-line, capacitance type moisture meter. These instruments are of great value in providing quality assurance feedback and their use will expand as both producers and consumers become more sophisticated.

NATIVE SOFTWOOD

Logging of the native softwood resource is now limited almost entirely to cypress pine, which is a slow growing, dense and knotty softwood. It occurs in fairly pure stands to the west of the coastal ranges in New South Wales and Queensland where the rainfall is between about 500 and 900 mm per year. Fig. 1 illustrates the size and sustainability of this resource.

Cypress pine is used green for scantling but it is often seasoned for use as board products, such as feature panelling, flooring and cladding. The cypress industry is quite scattered and the sawmills are relatively small. Air seasoning has been practiced successfully because the prevailing rainfall and relative humidity are quite low. However, kiln drying provides more flexibility in the market and kilns are beginning to gain acceptance. Some dehumidifier kilns have been installed in New South Wales, and there are some glass-house type, solar kilns in Queensland, based on the design developed by Gough (1981).

IMPORTED SAWNWOOD

The largest volume of sawnwood imported green and dried in Australia is western red cedar (*Thuja plicata*) from the west coast of North America (mainly Canada) used for cladding, lining and exterior (window) joinery. Small quantities of meranti (*Shorea* spp.) from south-east Asia are also dried in Australia, but most is imported already dried - often as milled products. Both timbers dry easily with little degrade, and are air dried and/or kiln dried in the metropolitan timber yards of the importers or manufacturers.

Kiln drying is usually at low temperature in conventional or dehumidifier kilns. The latter appear to be particularly suitable for the uncritical requirements of these drying operations, and may be used increasingly in the future.

Minor quantities of other imported species are air dried for some specialist products, e.g. Douglas fir (*Pseudotsuga menziesii*) for scaffold planks, ladder stiles, etc.

CONCLUSION

The production of dried timber in Australia will continue to increase. Almost all the increase in sawn softwood will be kiln dried, and the proportion of sawn native hardwood that is kiln dried will increase, for use as dried structural timber and in value-added appearance products. The main objectives in kiln drying any species are -

> To reduce the mean MC of a kiln charge to a nominated target value, with minimal variation in MC throughout the charge or within individual pieces. The target MC should normally correspond to the anticipated service EMC to minimise subsequent movement.
>
> To restrict drying degrade - warp, checking, the effects of collapse, and residual drying stresses - to limits appropriate for the intended use.
>
> To achieve these aims in the most cost effective way.

Severe drying conditions - high temperature drying - are, and will continue to be, used for almost all plantation softwood sawnwood and, increasingly, for the final drying of native hardwood from below FSP. Excellent results can be achieved, but the tolerance for error is less than with slower, less exacting drying processes. A combination of good kiln design and good kiln operation is essential. Both are becoming more attainable using computer-aided performance modelling in kiln design, and programmable, computerised kiln monitoring and control systems. The only concern is that commercial considerations in many cases result in compromises - (a) in kiln design, to obtain the construction contract and (b) in operation, to reduce drying times and costs.

An ongoing commitment to research and development in kiln drying is necessary to provide -

> A better understanding of the processes involved, with more information about the properties of individual species, enabling improved modelling and leading to better control of the drying process.
>
> Continuing development of commercial drying operations.

This should ensure the successful future growth in the production of dried sawnwood.

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HACIA UN SECADO DE MADERA MAS EFICIENTE

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RESUMEN

La investigación del secado de madera ha creado una sólida base teórica para el desarrollo del sector. El interés general por modelar procesos físicos y la disponibilidad de computadores de bajo costo, están contribuyendo para que este conocimiento sea utilizado progresivamente para mejorar los métodos y los programas de secado, los diseños de secadores y el control de los procesos.

Avances en el secado a alta temperatura revelan que este método de secado presenta múltiples ventajas frente al secado tradicional para secar un número creciente de especies en ciclos muy reducidos. Se discuten las publicaciones relevantes y algunos resultados experimentales.

Existe un interés creciente por presecar maderas latifoliadas propensas a agrietarse y a colapsar en secadores de bajo costo. Se discuten las tendencias actuales y se presentan algunos resultados experimentales.

SUMMARY

Research in wood science and technology has created a strong theoretical basis for a further development of this field. The general interest for modeling physical processes and the availability of cheap computers are contributing to use this knowledge progressively to improve drying methods and schedules, kiln designs and process control.

Advances in high temperature drying show that this method has several advantages over the conventional drying to dry an increasing number of wood species in very short cycles. The relevant publications and some experimental results are discussed.

There is an increasing interest for predrying hardwoods which are prone to develop surface checks and to collapse, in low cost kilns. Current trends are discussed and some experimental results are presented.

INTRODUCCION

En el secado convectivo el aire húmedo aporta el calor sensible para secar un sólido y también es el medio por el cual se evacúa la humedad liberada. En la mayoría de los métodos de secado de madera se aplica este proceso, independientemente de la forma utilizada para reacondicionar el aire húmedo y de sus niveles de temperatura, humedad y presión. Es probable que en el futuro se siga empleando prioritariamente este proceso para secar madera, por lo que a continuación se hará referencia principalmente a los avances relacionados con el secado convectivo.

El flujo de calor sensible, aportado por el aire, debe vencer la resistencia de la capa límite convectiva, y, al secarse la superficie, la resistencia adicional de la madera más seca entre ésta y el agua libre interior. En el sentido inverso el flujo de humedad debe vencer las resistencias de la madera y de la capa límite para migrar como agua líquida y como vapor. En estas condiciones en el secado convectivo siempre se superponen un gradiente de temperatura hacia el interior del sólido, con otro de humedad hacia el exterior, siendo el último el más problemático. Como la madera se contrae progresivamente bajo el punto de saturación de sus fibras, dicho gradiente de humedad impone deformaciones y tensiones que varían durante el secado y son la causa de grietas y deformaciones. El cuadro anterior se complica aún más por la anisotropía de la madera, que se caracteriza porque las contracciones y los módulos resistivos varían según la dirección considerada y por otras variables propias de la anatomía de la madera considerada.

La madera también exhibe un comportamiento viscoelástico, que se presenta preferentemente sobre 70°C y favorece la deformación plástica con menores esfuerzos. Esta propiedad también depende de la humedad del sólido y del tiempo durante el cual la madera está bajo tensión. Como la resistencia de la madera para enfrentar el agrietamiento durante el secado disminuye con la temperatura, existirán secuencias óptimas de condiciones de secado para cada tipo de madera, que permiten acelerar el proceso minimizando los defectos de secado.

La investigación de estos programas de secado y el diseño de equipos y sistemas que permitan realizarlos y controlarlos con un costo mímino, seguirán siendo los temas centrales de la investigación del secado de madera.

DE LA TEORIA A LA PRACTICA

En muchas áreas de la ciencia y de la tecnología se puede identificar períodos de desarrollo iniciales, en que ambas tuvieron un desarrollo paralelo, sin complementarse significativamente: Los científicos creaban conocimiento que los ingenieros no podían utilizar para transformarlo en tecnología. Un ejemplo notable lo constituye el desarrollo de la hidrodinámica durante el siglo pasado, realizado preferentemente por connotados matemáticos. A pesar de los avances logrados, los hidráulicos de la época no pudieron utilizarlos, porque los primeros no resolvieron los problemas asociados a la fricción en las paredes. Recién el descubrimiento de la existencia de una capa límite, por L. Prandtl en 1905, favoreció la integración de ambos sectores en la mecánica de fluidos. Es posible generalizar la conclusión, que los grandes desarrollos se producen cuando los teóricos y los prácticos se complementan activamente.

Aparentemente estamos presenciando un desarrollo similar en el secado de madera, aunque en forma menos evidente. El conocimiento empírico acumulado durante muchos años está siendo reemplazado progresivamente por los resultados obtenidos con modelos matemáticos, para desarrollar programas de secado, para diseñar secadores y para controlar los procesos. Aquí como en otros casos el desarrollo de la computación ha favorecido el acercamiento de los teóricos y prácticos.

Durante las últimas dos décadas ha existido un vivo interés por interpretar matemáticamente la migración de la humedad en el interior de la madera. Los modelos difusionales, basados en la 1ª o la 2ª ley de Fick (Stamm 1964, Choong and Skaar 1969)*, dieron lugar a modelos más sofisticados, que consideraban coeficientes de transporte diferentes para el líquido y el vapor (Krischer 1956, Luikov 1975). Siguieron los modelos que consideraban que la migración del agua ligada se debe a la existencia de un potencial químico (Kawai et al. 1978) y al efecto Soret o difusión térmica (Siau 1980). Skaar et al. (1982) postularon que el potencial rector del movimiento de agua ligada es una función termodinámica, que llamaron "spreading pressure". Nelson (1986) desarrolló este concepto y presentó ecuaciones de flujo convalidadas experimentalmente. Stanish et al. (1986) desarrollaron un modelo unidimensional, que plantea el transporte simultáneo de calor, agua libre, vapor y agua ligada. Para su solución consideraron que siempre se cumple el equilibrio de las fases presentes. Los autores también presentaron el planteamiento general de la solución matemática empleada (1986).

Los modelos desarrollados permitieron a sus autores conocer mejor los procesos de transporte en el interior de la madera durante el secado. Sin embargo son demasiado complejos para simular el secado de muchas tablas en un secador, por lo que modelos semiempíricos como los de Bramhall (1976) y Rosen (1987) mantuvieron su vigencia. También cabe destacar el modelo estadístico de Kayihan (1985), que aparentemente ha sido de gran utilidad para sus autores por su simplicidad y porque requiere conocer sólo algunos coeficientes fácilmente determinables para ser aplicado.

Los modelos citados no consideran el desarrollo de esfuerzos en la madera. Ashworth (1980) y Lamvik (1982) publican métodos para sistematizar el desarrollo de programas de secado basados en la limitación de esfuerzos causados por gradientes de humedad. Este tópico se torna particularmente interesante si se consideran los nuevos reconocimientos de Hillis y Rozsa (1985), Guitard (1987) y Genevaux (1989) sobre el comportamiento viscoelástico de la madera.

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* Sólo se presentan las citas completas de las contribuciones relacionadas con el secado a alta temperatura y el presecado artificial, que son los temas centrales de este trabajo.

Más antecedentes sobre el transporte de humedad en la madera son aportados por Rosen (1987). Quarles y Wengert (1989) presentaron un excelente resumen de las publicaciones relativas a investigaciones aplicadas en secado de madera, realizadas preferentemente en Norteamérica en el último decenio.

Los computadores son cada vez más poderosos y permiten resolver grandes sistemas de ecuaciones, por lo que en el futuro se desarrollarán modelos que considerarán la transferencia de calor, el transporte de humedad en diferentes formas, el desarrollo de tensiones en el interior de la madera y su relajación viscoelástica. Sin embargo, seguirá siendo un desafío permanente encontrar leyes físicas y sus expresiones matemáticas que simplifiquen el problema, de tal manera que los modelos puedan ser aplicados a cargas completas en diferentes condiciones de operación de un secador. Sólo modelos relativamente simples podrán se absorbidos por fabricantes de secadores y por expertos, para que éstos optimicen los diseños, los programas de secado y su control de acuerdo a los nuevos conocimientos.

A pesar del escepticismo inicial, los productores de madera norteamericanos han ido aceptando los sistemas de control electrónicos y/o computarizados, que son muy populares en Europa desde hace 20 años (Mackay 1988, Brunner 1985). Presumiblemente en el futuro se seguirán empleando controladores que combinen ciclos predictivos con otros adaptivos, en que se mide directa o indirectamente la humedad actual de la madera para ajustar las condiciones de secado. Algunos expertos vaticinan que en el futuro la estrategia de control será del tipo distribuido, aunque otros son más escépticos (Holmes 1988).

Los sensores de humedad de la madera siguen siendo deficientes, por lo que muchos fabricantes de equipos de control están optando por determinar la humedad media en varias zonas de un secador en forma indirecta. Cabe destacar la importancia creciente de la utilización de la caída de temperatura a través de la pila como variable de control. Es probable que en el futuro se utilice en mayor escala computadores de bajo costo, para controlar el secado de madera integrando a los modelos variables fácilmente medibles y parámetros característicos de cada secador.

Un buen secador debe ser diseñado de acuerdo a las necesidades presentes y futuras del productor. Estas pueden ser muy variadas y deben considerar el tipo de madera, los volúmenes de producción, la disponibilidad y el costo de energía, la disponibilidad de personal especializado para operar y mantener el secador, etc. Es probable que incluso los secadores de fabricación reciente puedan ser mejorados significativamente si consideran los avances recientes.

A continuación se presentarán algunos resultados recientes en relación al secado de alta temperatura y al secado artificial desde verde de maderas propensas al colapso. Ambos temas están siendo investigados en varias partes del mundo y seguirán siendo de interés general.

SECADO A ALTA TEMPERATURA

La historia de este proceso es bastante conocida y es sorprendente cuánto tiempo tuvo que transcurrir, hasta que se transformó en una realidad industrial. Al respecto cabe destacar el trabajo pionero realizado por el CSIRO en Australia (1983).

Actualmente ya no se cuestiona que el secado a alta temperatura es el método de secado más eficiente para secar coníferas permeables como el pino radiata (Pinus radiata D. Don) en Australia y Nueva Zelandia, el pino sureño (Pinus taeda) en Estados Unidos y el pino marítimo (Pinus sylvestris) en Francia. La lista de especies, que pueden ser secadas a temperaturas sobre 100°C desde verde, aumenta continuamente e incluso el secado de maderas latifoliadas es posible a temperaturas sobre 110°C (Cuevas 1974, Boone 1984 y Christensen 1984). Este último investigador también destaca que es económicamente atractivo secar el eucalipto delegatensis a temperaturas sobre 100°C, en menos de 10 horas desde el punto de saturación de la fibra. Koch (1976), Tomaselli (1977) y otros autores indicaron que la madera secada a alta temperatura tiene resistencias mecánicas similares a la secada según otros procesos.

Para lograr un buen secado a alta temperatura se debe cuidar algunos aspectos relativos al diseño de los secadores y al proceso, que no siempre se han respetado. Christensen (1982) destacó la importancia de la velocidad del aire a través de la pila, especialmente a altas temperaturas.

Lo anterior se debe a que los coeficientes convectivos de transferencia de calor y materia en la capa límite del aire aumentan con la velocidad y, lo que es más importante, a que la fuerte evaporación disminuye la temperatura del aire a través de la pila. Por ello y para lograr un secado homogéneo, las pilas deben ser angostas y las velocidades altas (CSIRO, 1983).

Es conocido que el uso de pesos sobre las pilas evita los alabeos (Northway 1981), lo que es especialmente importante cuando se secan maderas juveniles con médula, que han tenido un crecimiento helicoidal. Según Northway y Christensen (1981) para estas maderas el vaporizado inicial, recomendado por algunas asociaciones (RPAA 1979), parece no ser necesario.

Para simplificar el control y para poder predecir más fácilmente cuándo se ha alcanzado la humedad final deseada, en general se ha recomendado mantener constantes las temperaturas de bulbo seco y bulbo húmedo. Se recomienda que el calentamiento se realice en 1 a 2 horas (Williams y Kininmonth 1984).

En las figuras 1 y 2 se muestran los resultados de ensayos de secado realizados con madera de pino radiata de 55 mm de espesor y velocidades del aire de 5 m/s. La temperatura de bulbo seco se mantuvo en 120°C y la de bulbo húmedo en 70°C. Llama la atención que la temperatura superficial sube rápidamente sobre la temperatura de bulbo húmedo y pasa los 100°C, lo que muestra que el período de secado constante es muy corto y que la humedad del aire no afecta mayormente la calidad de la madera. Se puede concluir que este secado es muy parecido al que se podría esperar con vapor sobrecalentado, salvo que este último proceso requeriría menos energía térmica, porque se evita el calentamiento de aire frío. Por otro lado sería más corrosivo.

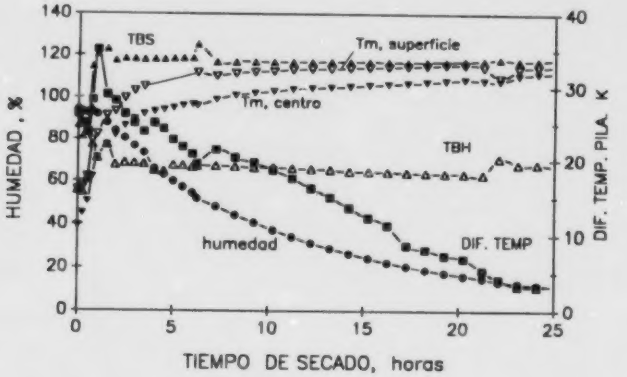

Figura 1: Evolución de temperaturas durante un secado a alta temperatura.

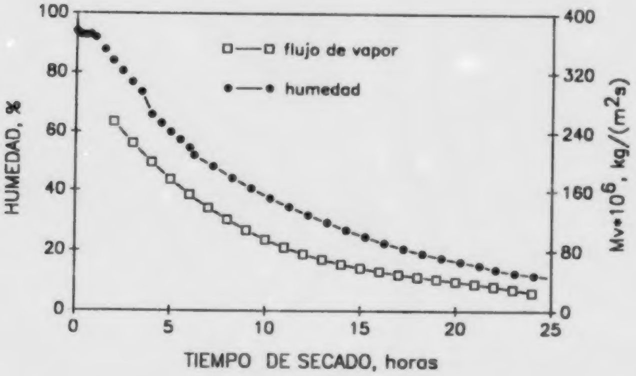

Figura 2: Humedades y tasas de secado durante un secado a alta temperatura.

La tasa de evaporación decrece durante el secado en un factor 10. Esto exige que la caldera y la superficie de calefacción sean dimensionadas para una carga puntual máxima, que aumenta significativamente la inversión inicial cuando existen pocos secadores. En la medida que la madera no se agriete, se debería buscar programas de secado que reduzcan dicho factor de sobredimensionamiento. Aparentemente algunas maderas, como el pino radiata, soportarían temperaturas mucho mayores sin que se produzcan defectos significativos (Northway 1989). Ensayos propios, realizados con pino radiata chileno, indican que a temperaturas hasta 140°C sólo se producen algunas grietas internas en las puntas.

Basilico et al. (1982) y Moyne (1982) mejoraron la base teórica de este proceso al determinar en forma experimental y teórica, que durante el período de secado decreciente se produce una presión de vapor superior a la atmósferica en el interior de la madera. Esta ayuda a evacuar el agua libre por los extremos siguiendo la ley de Darcy. Martin et al. (1989) muestran que se puede reducir la propensión a la formación de grietas en algunas maderas, si se cumple un cierto programa de secado en que se reduce la temperatura del aire y de la madera durante el período de secado decreciente.

El término del secado se determina normalmente en función del tiempo transcurrido desde el inicio del proceso o cuando la caída de temperatura a través de la pila ha disminuido bajo un valor semiempírico. En la medida que en el secado de alta temperatura se incorporen programas de temperatura variable, será deseable contar con un método más preciso para finalizar oportunamente el secado.

Todavía es necesario acondicionar la madera con vapor saturado, para disminuir los gradientes de humedad y las tensiones en el interior de la madera después del secado a alta temperatura. Es posible que en el futuro el secado con vapor sobrecalentado permita eliminar esta etapa que es bastante cara.

Antes de dar por finalizado el secado a alta temperatura, es necesario dejar cargada la madera durante al menos 24 horas. Según Williams y Kininmonth (1984) muchas grietas aparecen durante el enfriamiento.

El secado a alta temperatura tiene un futuro promisorio: En muchos casos ya permite obtener mejores productos, consume menos energía, es más económico y permite una producción más continuada. Es probable que en el futuro los programas de temperatura variable permitan un secado aún más rápido de más especies.

PRESECADO DE MADERAS PROPENSAS A AGRIETARSE

Muchas maderas latifoliadas de baja permeabilidad, como los eucaliptos, son propensas a agrietarse durante el secado inicial, por lo que tradicionalmente se han secado al aire o en grandes recintos acondicionados (Brennan et al. 1966). Se puede generalizar que el secado artificial controlado desde verde es más eficiente y más económico que el secado al aire y ofrece múltiples beneficios al productor (Vermaas, 1987). Esto se suele desconocer, especialmente en los países en vía de desarrollo.

El tema ha recobrado vigencia en Australia, EE.UU. (Wengert, 1985), Nueva Zelandia, Sudáfrica (Stöhr 1985, Vermaas 1987 y 1989) y en Chile (Neumann 1989), por la necesidad de secar madera de eucaliptos jóvenes, provenientes de grandes plantaciones. Como estos árboles son de menor diámetro, inevitablemente se produce una fracción apreciable de madera tangencial, que es muy propensa a agrietarse. La madera de corte radial es más fácil secar, pero propende al colapso, que es recuperable con un vaporizado o un tratamiento de muy alta humedad, cuando la madera haya alcanzado una humedad media de aproximadamente 20% (Neumann, 1979).

A continuación se presentan algunos resultados parciales del secado de madera de eucalipto globulus a muy bajas temperaturas. Básicamente se trató de mantener una temperatura de bulbo húmedo de 20°C y una diferencia sicrométrica pequeña.

En las figuras 3 y 4 se muestran los programas y las curvas de secado, así como las contracciones de 46 piezas de corte radial de 30 mm de espesor. La diferencia sicrométrica se fue aumentando durante el secado, en la medida que disminuía la aparición de nuevas grietas o las existentes no aumentaban su longitud. Se puede observar que las piezas de menor densidad, que normalmente tienen una humedad inicial mayor que las de mayor densidad, se secaron antes, de tal manera que la distribución de humedad al final del presecado fue bastante uniforme. En la figura 4 se puede observar que el espesor disminuyó fuertemente durante los primeros 15 días, lo que se debe al colapso de las células cuando se retira el agua libre. En general se presentaron menos defectos que en madera secada al aire con un clima templado.

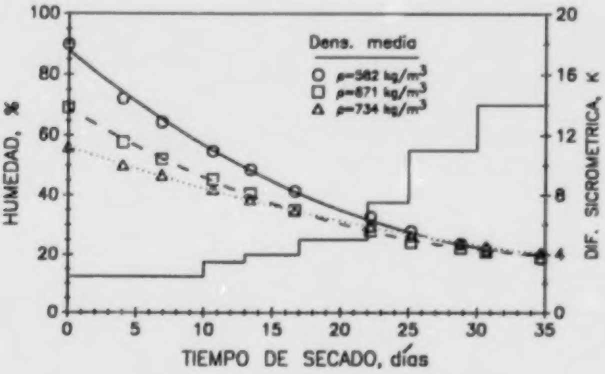

Figura 3: Curvas de secado para eucalipto globulus de 30 mm de espesor.

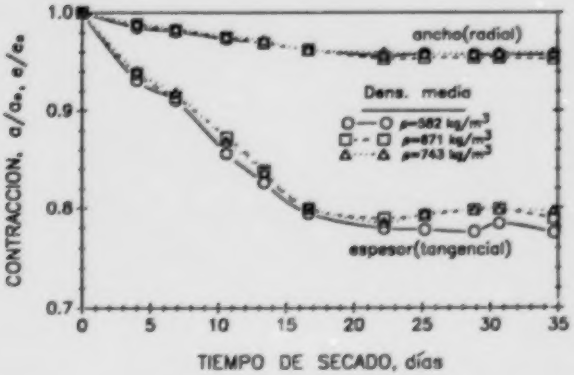

Figura 4: Contracciones durante el secado de eucalipto globulus de 30 mm de espesor.

En las figuras 5 y 6 se presentan algunos resultados del presecado artificial de madera de corte tangencial de 55 mm de espesor. En este caso las curvas de secado de tablas de diferentes densidades se cruzan a los 40 días, cuando la humedad media es de un 30%. En la figura 6 se puede observar que el colapso fue mínimo y que las grietas superficiales se desarrollaron preferentemente en las tablas de mayor densidad durante los primeros días, lo que corresponde con las mediciones de las humedades superficiales que se muestran en la figura 5. Si bien es inevitable que las superficies se sequen antes, es probable que mientras menores sean las tasas de secado al iniciarse el secado, menores serán los gradientes de humedad y la formación de grietas disminuirá. Otros ensayos mostraron que un aumento indebido de la temperatura en esta fase aumenta drásticamente la formación de grietas.

Christensen (1987) informa sobre el secador progresivo desarrollado por el CSIRO en Australia para presecar eucaliptos desde verde. El secador es muy interesante por su bajo costo y se está utilizando comercialmente. Una simulación del secador mostró que con el sistema de control existente se producen tasas de evaporación significativas en ciertos sectores después de correr la carga (Neumann 1989). Se propone algunas modificaciones que reducen dichas tasas, lo que debería disminuir el riesgo de formación de grietas en tablas de corte tangencial.

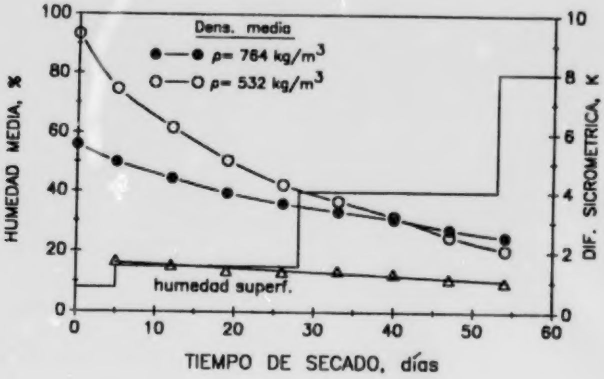

Figura 5: Curvas de secado para eucalipto globulus de 55 mm de espesor.

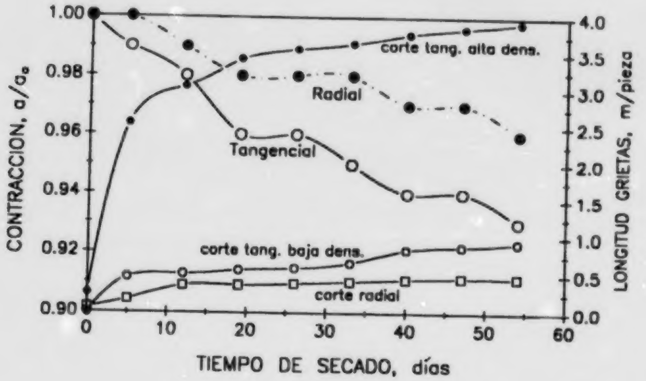

Figura 6: Formación de grietas y contracciones durante el secado de madera de eucalipto globulus de corte tangencial.

CONCLUSIONES

Se estima que la investigación del secado de madera, realizada durante las últimas dos décadas, ha sido significativa y permitirá tecnificar continuamente los procesos industriales. El proceso de desarrollo y transferencia tecnológica a los productores ha sido favorecido por el auge de la computación y por la disponibilidad de controladores electrónicos de bajo costo.

En el futuro probablemente seguirá existiendo una demanda por programas computacionales simples, que integren variables fácilmente medibles y parámetros del secador para controlar el proceso. También existirá interés por programas computacionales más complejos, que integren los fenómenos de transporte en la madera con la generación de tensiones y la relajación de éstas, dada la propiedad viscoelástica de la madera. Con ellos se podrán desarrollar programas de secado más eficientes y mejorar los diseños de secadores.

Nuevos conocimientos sobre el secado a alta temperatura permitirán seguir reduciendo los tiempos de secado, aplicar el proceso a más especies y reducir el consumo de energía. Al ir resolviendo los problemas de corrosión, presumiblemente el secado con vapor sobrecalentado irá sustituyendo el secado con aire húmedo a altas temperaturas.

El secado natural de especies difíciles de secar será sustituido por el presecado artificial en secadores de bajo costo. Algunos resultados experimentales presentados en este trabajo confirman que las ventajas son evidentes, especialmente si se mantienen condiciones de secado muy suaves durante los primeros días de secado. Será conveniente revisar los programas de secado de muchas especies, para determinar si es posible aumentar significativamente la temperatura del aire cuando toda la carga esté bajo el punto de saturación de la fibra y así reducir los tiempos de secado.

Finalmente cabe destacar la importancia creciente de los costos y la necesidad de orientar la producción según los requerimientos del cliente. Ello implica reducir los volúmenes de madera seca almacenados y responder con programas de secado cortos y confiables.

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DIISOCYANATE ADHESIVES DERIVED FROM RENEWABLE RESOURCES: PRELIMINARY RESULTS

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Adhesives play an important role in the wood products industry. In 1988 this industry accounted for a 25 percent share of the total U.S. consumption of adhesives. Urea-formaldehyde and phenol-formaldehyde resins were the dominant adhesives used.

In recent years several factors have created the necessity to investigate new types of adhesives. These factors include not only health and safety considerations arising from the need to reduce or eliminate formaldehyde emissions, but also the desire for improved performance characteristics of composite materials. Promising new adhesives are those based on isocyanate compounds, e.g., diphenylmethane diisocyanate (MDI). The excellent hydrolytic stability of the bonds formed makes isocyanate-bonded products suitable for interior and exterior applications. Moreover, formaldehyde emissions from isocyanate-bonded products are essentially the same as those from wood and thus do not constitute a problem. The most significant disadvantage associated with these adhesives has been their cost relative to conventional resin systems.

Another factor that has prompted industry's interest in new adhesive systems is its concern about future supplies of appropriate adhesives and its desire to be internally sufficient via elimination of its dependence on adhesives derived from petroleum. Although petroleum prices have declined from the maximum reached in the seventies and supplies have stabilized, the energy crisis demonstrated how rapidly the economic and supply aspects of industries based on petroleum-derived materials can change.

Renewable, biomass-based materials offer an alternate, non-petroleum source of adhesives. However, in order for an adhesive system based on renewable resources to be of practical utility, it must be as durable as existing petroleum-based adhesives and must cure at similar temperatures and pressures to ensure that plant productivity is sustained. In addition, the precursors for adhesive synthesis must be obtainable in sufficiently large quantities to ensure continued availability of the adhesive system.

Furfural is a renewable chemical that is presently produced in modest quantities on a world-wide basis. By-product streams in the forest products industry and other agricultural residues constitute large, untapped reservoirs of feedstock for furfural production. A number of adhesive resins based on furfural and its hydrogenation product, furfuryl alcohol, have been reported in the literature. These resins are utilized primarily as molding resins in the foundry industry; but, generally have not been acceptable as wood adhesives. Derivatives of furfural, in particular those based on furfurylamine, are possible precursors of resins that might have utility as wood adhesives. Recently, the synthesis of difurfuryl diisocyanates from furfurylamine was reported in the literature. These compounds have reactivities intermediate between those of aliphatic and aromatic diisocyanates. Preliminary experiments strongly suggest that they can be used as wood adhesives. Results from these preliminary experiments will be discussed.

PROCESSING

The bulk of the sawnwood is produced by either very big or very small sawmills. 18 % comes from seven big mills each of which has an annual production in excess of 50,000 m3, several of them around 100,000 m3. The remainder is distributed as shown:

20,001 to 50,000 m3/year - 14 % (11 mills)
10,001 to 20,000 m3/year - 8 % (19 mills)
5,001 to 10,000 m3/year - 9 % (44 mills)
below 5,000 m3/year - 51 % (1500 mills)

In the larger mills, the equipment is generally modern with either band or gang saws for breakdown, but automation is not as advanced as in many Northern Hemisphere countries.

Drying kilns are found only in the larger sawmills. Only 9.5 % of the sawnwood produced are kiln-dried, i.e. a volume of about 250,000 m3.

Similarly, preservation is not a common practice. Not more than 16 mills have impregnation plants and these are not used to full capacity. Mostly preservation is carried out only to satisfy special orders where treatment is explicitly demanded by the customer. This state of affairs is mainly due to the fact that the country has not yet promulgated any standards with respect to the preservation of timber for construction. At present sawmills are not prepared to carry a stock of sufficient magnitude of treated timber of the various dimensions required. According to statistical surveys, only 15,600 m3 of timber are treated annually.

Timber buildings and dwellings account for a built surface of 548,400 m2 per annum which represents 13,8 % of the Chilean total of 3,980,000 m2. In addition, timber is present in combination with bricks in another 8,9 %.

Lamitated wood has been introduced only recently on a significant scale and predominates in industrial and commercial buildings. The annual demand in terms of different products is

Trusses	3990 m3	Frames	1500 m3
Beams	2700 m3	Curved elements	1000 m3
Arches	1500 m3	Pillars	650 m3

A standard specification governing calculation and design of timber structures (Norma chilena 1198) is at present submitted to public consultation. It will regulate and uniformize the engineering design of the structure of common timber buildings, structural elements of timber in combination with other materials, scaffolding, mouldings, pallets, containers, bridge timbers, posts, etc.

RESEARCH

Research on wood science and technology in Chile is undertaken in several universities (Universidad de Chile, U. del Bio Bio, U. de

A METHOD FOR THE UF RESINS FORMULATOR: DETERMINATION OF UF RESINS ADHESION

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FDC: 824.834: 813.1: 824.89--015

ABSTRACT

A calculation method for the quantification of total adhesion of UF resins to lignocellulosic substrate is exposed. The method is based on the matching of the values of specific adhesion of each simple UF oligomer to crystalline and amorphous wood carbohydrates, with their percentual distribution as a function of reaction time. The method allows simple scanning of the variation of adhesion of a UF resin according to changes in formulation and process of manufacture. Its application to known practices in UF resins manufacture, such as second urea addition, shows consistency with experimental evidence and allows for the first time calculated quantification of the relevant effects. The method allows simplified and rapid screening of UF formulations as regards adhesion and is shown to have the capability of indicating in which manner UF resins formulations and processes could be changed to maximize adhesion and adhesives performance. For all this, it should be considered an invaluable and simple tool for UF adhesives formulators.

ORGANOSOLV LIGNIN-MODIFIED PHENOLIC RESINS FOR PLYWOOD ADHESIVES

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SUMMARY

An adhesive system for structural plywood is demonstrated in which 40% of the resin solids of a phenol-formaldehyde resin are successfully replaced with an organosolv hardwood lignin. Molecular weight and formulation characteristics of the resins are included. The plywood test results, including shear strength and estimated wood failure values, support the use of organosolv lignin as a partial substitute for phenol in structural wood adhesives. The bulk properties of the lignin were characterized before and after its purification with aqueous sodium bicarbonate solution and reported earlier in the 1989 ACS Symposium Book Series 397, Lignin: Properties and Materials.

Keywords: Adhesives, lignin, organosolv pulping, phenol-formaldehyde resin, plywood

INTRODUCTION

For many years in the United States, phenol-formaldehyde (PF) resin has been the preferred adhesive for bonding weather-resistant wood products such as structural plywood and flake boards (Conner and Lorenz 1986). Together, these panel industries consume about 360 million kg (794 million lb) of PF resin solids (Myers 1988). The PF adhesive accounts for about 10% of the manufacturing costs of structural plywood and 20% of the costs of flake boards (e.g., oriented strand boards and wafer boards) (Koch, et al 1984). Phenolic resin prices, generally paralleling phenol prices, have been increasing over the past decade. The increasing PF prices have directed attention to alternative sources for these adhesives or their chemical feedstocks.

Lignins offer promise as an alternative source of adhesives. Lignins constitute approximately one-quarter of the weight of dry wood and represent a plentiful naturally occurring polymer, second in abundance only to cellulose. Unfortunately, most available lignins come from kraft and sulfite pulping and their structures (phenylpropane and methoxyl groups) restrict reactivity and limit the usefulness of lignin-based resins for wood bonding. If these lignins are refined to increase reactivity, their costs will increase.

Organosolv lignin (OSL) may provide the solution for cost efficient use of lignins for adhesives. Although OSL have a higher purity and reactivity than lignins from conventional pulping methods, very little has been published on the use of OSL in phenolic adhesives. Pulping methods which use organic solvents are particularly well-suited for solubilization of the lignins from wood and are known to be readily coupled with efficient solvent recovery systems (Chemical Week 1984). Although an organosolv pulping plant does not exist and commercial organosolv lignin is not available in the United States, a pilot plant in Canada began production in 1989 (Lora et al 1989).

This study evaluated organosolv hardwood lignin as a substitute for phenol in the ranges of 30%, 40%, and 50% in the PF resin formulations used to bond plywood. The OSL-PF bonded plywood was compared to control PF bonded panels for shear strength and bond-line wood failure properties.

EXPERIMENTAL

Resin Preparation

A control PF plywood-type resin and experimental resins with substitutions of purified OSL ($NaHCO_3$-washed) for phenol at 30%, 40%, and 50% levels in the PF resin were formulated (Table 1). The synthesis of OSL-modified PF resins were developed by an initial methylolation of lignin for 30 to 90 minutes followed by a sequential in-situ methylol-lignin, phenol-formaldehyde condensation step of 3 to 5 hours. The molecular weights of the resins were determined by gel filtration chromatography (GFC) using Sephacryl 200 HR as gel (Mississippi Forest Products Laboratory 1987). Sodium-polystyrene-sulfonate standards were used as reference compounds. Other resin properties were determined by standard methods, including nonvolatile solids, viscosity, pH, free formaldehyde, alkalinity, and gel time (Table 2).

Table 1: Typical stoichimetric properties of resin reactants and molecular weights of finished resins

Charged ingredient	Lignin/phenol ratio 0/100	 30/70	 40/60	 50/50
		Amount (mol)		
Water	35.25	26.95	33.56	34.05
Sodium hydroxide, 50%	3.74	2.78	3.59	3.76
Lignin[a]	--	1.02	1.67	2.09
Formaldehyde	15.82	12.65	15.51	15.55
Phenol, 90%	8.48	5.05	5.33	4.45
Molecular weight				
M_w	7068	4127	5228	5459
M_n	2876	956	1492	1654
M_w/M_n	2.45	4.31	3.50	3.29

[a] These values assume a mole equivalent unit of 200 based on a typical analyzed C_9 lignin unit.

Table 2: Typical physical properties of phenol-formaldehyde and lignin-modified phenolic resins

Property	Unit	Lignin/phenol ratio 0/100	 30/70	 40/60	 50/50
Nonvolatile solids (105°C)	%	43.19	44.21	43.94	42.97
Gel time (100°C)	min	25.30	22.40	18.20	16.60
pH	--	11.20	10.85	10.20	10.35
Free formaldehyde	%	0.06	0.48	0.90	2.75
Alkalinity	%	5.01	4.33	3.64	3.52
Viscosity (25°C)[a]	mPa.s	1020	1220	1080	1130
Specific gravity (25°C)	--	1.175	1.186	1.055	1.134

[a] The viscosity was determined by Brookfield Model RVTD, No. 21 spindle, 5.2 rad/s (50 rpm).

Plywood Screening Method

Rotary-cut southern pine veneers were obtained from a commercial structural plywood plant. The dried veneers were 4.2-mm (1/6-in.) thick, "C and Better" grade, and varied from 1.2% to 4.8% in moisture content. The veneers were cut to 0.3 by 0.3 m (1 by 1 ft). To simulate the actual adhesive mix used in commercial production of plywood, soft wheat flour and pecan shell flour were added to each resin formulation as fillers (extenders). The fillers were wetted and dispersed in the mix with water and sodium hydroxide. For each resin, twenty-four 3-ply, 12.7-mm (1/2-in.) thick plywood panels, 0.3 by 0.3 m (1 by 1 ft) in size, were made [3 assembly times (20, 40, and 60 min); 2 press times (4 and 6 min); and 4 replications]. A total of 96 panels were made (4 resins, 24 panels each). Panels were assembled after using a roll coater to apply an adhesive spread of 224 g/m^2 (46 lb/1000 square feet of single glue line). The assembled panels were cold pressed (ambient temperature) at 1103 kPa (160 psi) and were hot pressed at 1379 kPa (200 psi) and 150°C (302°F).

The bonded panels were tested according to the U.S. Products Standard PS I-83, plywood shear tests for exterior application (National Bureau of Standards 1983). The shear test specimens were 82.5-mm (3.25-in.) long by 25.4-mm (1-in.) wide and kerfed to provide a 25.4-mm (1-in.) square shear area. The specimens were subjected to 4 hours of boiling, 19 hours of drying, and 4 hours of reboiling. The specimens were then cooled in tap water and tested wet. The tension shear strength was recorded, and the wood failure of the shear area was visually observed and estimated to the nearest 5 percent.

The PS I-83 standard requires a minimum of 85% wood failure (a maximum of 15% glue-line failure) on tests for plywoods subject to adverse environments (exterior or wood preservative treatments) and 80% wood failure for plywood bonded with exterior adhesives having interior applications (interior plywoods usually allow lower grades of veneer).

RESULTS AND DISCUSSION

Previous reports have discussed the test results for laminated maple wood and flake board bonded with red oak OSL (Cook and Sellers 1989, Sellers et al 1988). The OSL successfully replaced phenol at 40% levels in PF resins used to bond laminated maple wood and at 35% in PF resins used to bond southern pine flake boards. In essence, the OSL has less sulfur and lower molecular weight than purified kraft lignin. Purification of the OSL (90% yield) by aqueous reslurry in 10% sodium bicarbonate solution removed low-molecular-weight impurities (e.g., mono-functional lignin-related species, waxes, and carbohydrates) and enhanced the usefulness of OSL [illegible] phenolic resins.

In this study, 30% to 50% of the phenol resin solids were substituted with red oak OSL in the PF resin used for bonding southern pine plywood. After the accelerated aging (two 4-h boil) test procedure, the plywood test specimens did not show any observable delamination (National Bureau of Standards 1983). In general, OSL-PF resin with 30% phenol replacement performed equal to the control PF resin in test panel properties (Tables 3 and 4). At 40% substitution, the OSL-PF resin had panel test properties comparable to those of control PF bonded plywoods with longer panel assembly times (40 to 60 minutes). However, at the shortest assembly time of 20 minutes, the 40% substitution OSL-PF resin proved to be deficient. This deficiency at short assembly times (as noted by the low wood failure appearance of the sheared glued line, Table 3) relates to water in the adhesive spread not equalizing into the wood and to slower cure of the resin.

Table 3: Wood failure percentages of plywood shear specimens for all processing variables

Assembly time (min)	Press time (min)	Lignin/phenol ratio			
		0/100	30/70	40/60	50/50
		%	%	%	%
20	4	94[a]	94	46	43
	6	96	98	70	43
40	4	96	97	91	80
	6	96	97	91	80
60	4	97	97	90	82
	6	97	96	96	88
Average		96	96	81	69

[a] Values represent average wood failure percentages of 40 shear specimens (4 panels, 10 specimens per panel).

Panels bonded with 50% substitution of phenol in OSL-PF resins were not comparable to control PF bonded panels and demonstrated even lower performance levels (lower wood failures) at short assembly times than resulted from the 40% phenol substitution.

Table 4: Tension shear strength of plywood test specimens for all processing variables

Assembly time (min)	Press time (min)	Lignin/phenol ratio			
		0/100	30/70	40/60	50/50
		kPa	kPa	kPa	kPa
20	4	1076[a]	1014	979	814
	6	1220	1089	1007	993
40	4	1062	979	1096	965
	6	1014	1062	1041	1020
60	4	896	896	1193	1020
	6	1976	986	1069	910
Average		1057	1004	1064	954

[a] Values represent average shear strength in kPa of 40 test specimens (4 panels, 10 shear specimens per panel). To convert values into psi, multiply kPa by a 0.145 factor.

CONCLUSION

Red oak OSL can be used to replace 30% to 40% of the resin solids in phenol-formaldehyde resins used to bond southern pine plywoods without adversely affecting the physical bond properties. While the pulping process that produces the by-product OSL does not commercially exist in the United States, a new Canadian plant should make OSL available by 1989. Lignins from such pulping processes are projected to cost 40% to 50% less than phenol as a polymer material. This reduction in raw material costs would translate into a 12% resin cost saving for a phenolic resin (43% nonvolatile solids types), other factors not being considered (e.g., extra storage, cook procedure differences, etc.)

ACKNOWLEDGEMENT

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THE COMMERCIALIZATION OF PINE TANNIN ADHESIVES IN CHILE

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ABSTRACT

FDC: 866.4: 824.85: 174.7 *Pinus* spp.

The results of fingerjointing and glulam industrial trials in Chile using a "honeymoon" fast–set adhesive system manufactured using commercially–produced pine tannin extract are reported. The results obtained satisfy standard specifications. A new "honeymoon"–type adhesive formulation had to be developed due to the peculiar gelling characteristics of the pine tannin extract used.

The Chilean pine tannin extracted from a mixture of Pinus insignis and Pinus radiata species shows gel times longer than what has been reported for other conifer tannins. Such differences in curing rate are tentatively reported to the relative branching of the different conifer tannins.

A MODEL OF COMPUTER AIDED OPTIMIZATION OF SAWING LOGS

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SUMMARY

The idea of precise log dimension measurement, log quality survey and log form determination before sawing on log band saw, to get both maximum yield from each log and to satisfy a certain specification of sawmill final products (e.g. furniture parts), should not necessarily give satisfactory results.

Another - we believe more succesful - approach at solving both maximum log yield and satisfation of wanted specification in the form of dimension stocks (mostly furniture parts) may be performed on the basis of the following principles: log is porposed as a truncated circular cone; presorting of logs according to specific criteria to each production specification (of dimension stocks), logs of specific characteristics are chosen; optimization of the log yield is performed by linear programing which is performed step by step.

Key words: computer in sawmilling, optimization, simulation, linear programing.

INTRODUCTION

Sawmilling in Yugoslavia is today organized as two main technologies: 1) the so-called classic technology, and 2) the technology of specified sawn elements (dimension stocks - mostly furniture parts and other semifinal and final products). Classic technology is characterized generally by one phase, continual process of log sawing in larger and smaller boards for unspecified products and unknown buyer - products for the market, according to the Yugoslav standard of sawn materials. The technology of sawn elements is characterized mainly by production of rough semifinal products for certain final products (furniture parts, window and door elements, parquet, etc.) and for known buyers. It is organized usually as a two-stage production (log break-down and resawing of primary boards in sawn elements - dimension stock). This technology may be separated by location (primary sawmill and the one for dimensions) and time (depending on whether the dimensions are produced in green condition - a continuous process, or dry condition - a two or three stage process).

Logs in Yugoslav sawmills are sawn either on frame saws or on band saws. Many of the softwood sawmills are using frame saws for the average log dimater up to about 35-40 cm (especially in classic sawmills). Larger logs are sawn on band saws. Hardwood sawmills are using today mostly classic one-blade log band saws and band resaws with the aim of achieving highest possible quality and value yield (money/m3 log). As a rule, only thinner logs (not over 30-35 cm average diameter), and especially those of poor quality (many knots) are sawn on smaller frame saws - looking mostly for higher productivity rather than quality yield, which is hardly obtainable on band saws too.

On the band saw sawmills, the yield of logs in the form of unedged and semiedged primary boards and planks is about 70%, whereas the yield from boards in the form of rough elements is about 50%, varying very much with the size and quality of boards and those of produced elements. Thus, altogether about 35% of logs is utilized in the form of sawn wood, and the residue (including the waste due to shrinkage) makes 65%. Any considerably higher log utilization influenced by sawmilling at present is associated with the introduction of computer technology and mathematical modelling.

The problems of increasing log yield by using computer technology have been dealt with for about twenty years by a number of authors (Hallock, Bulgrin and others, 1970). At the Institute of wood investigations at the Faculty of Forestry, University of Zagreb, first results in this field were published later (Hitrec, 1978). Our investigations started with the improvement of log utilization at sawing fir logs on frame saws. The investigation resulted with a computer program called RARAVO, well known at home and abroad (Brežnjak, 1979; Hitrec, 1980; Karkkainen, 1981). This program enabled making tables for reading the quantity yield of logs for the production of boards, their dimensional structure, and corresponding residues and waste (due to shrinkage and sawing inacurracy), all based on simulated sawing. Experimental sawing which followed (Butković, 1985; Stupar, 1988) gave the required coefficients for reduction of the theoretical log yield in RARAVO tables, to get reliable yield figures to be used in practical sawmilling. The difference between theoretical and experimental real log yield proved to be from 2% to 5%.

The RARAVO tables have been followed by RAVIDI tables, which gave the value yield from logs. The RAVIDI computer program was based (as a continuation of RARAVO program) on different prices of boards and planks of various standard sizes, as well as on the prizes for different type of residue.

REVIEW OF MAIN INVESTIGATIONS OF SAWING OPTIMIZATIONS

However, the methods of optimizing the yield of fir logs known as RARAVO and RAVIDI computer programs do not respond sufficiently to sawing optimization of hardwood logs (oak and beech - most important for Yugoslav conditions) on band saws. The reason for this is twofold: a considerable deviation of hardwood real logs from the truncated circular cone (which deviation proved to be rather small in fir logs) and their much greater wood quality variations (knots, splits, irregualr cross-section, taper, bow, and various interior deffects).

The first ideas about optimization of sawing hardwoods on band saws that we encountered required surveying of logs immediately before sawing. A log was surveyed in segments, whereupon the results were entered in the computer. By means of computer and formerly elaborated methods, i.e. programs, optimal sawing of *THAT* particular log was made (Lewis, 1985). We do not know exactly whether this way of optimization of sawing on classic one-blade band saws with carriage is implemented in sawmilling practice and what are the practical results of that method. Nevertheless, the analysis of this idea itself, we think, highlighted some difficulties:

The first problem is log quality. In our opinion it is too expensive and practically impossible to survey *all* relevant quality factors. This specially refers to the many inside factors of quality, such as red heart in beech logs. As far as we know, recent investigation at the Mississippi University in Starkville, of the use of x-rays for determination of deffects inside boards is still on laboratory level (Butkovic, 1989). The problem is that the optimal first cut, i.e. optimal sawing is very susceptible to every quality variation. However, in the attempt to survey the log thouroughly before sawing, we have to bear in mind that we are doing approximations whose values we do not know.

Another problem is time. The measurement of log dimensions, error survey, result computing, calculation of optimal sawing, and positioning of logs into the desired position all require too much time to be technologically and economically appropriate. The reduction of time leads, on the other hand, to increasingly rough approximations. The idea that every log before being stored aside is surveyed and numbered is possible, though it requires additional manipulations and increases the costs of the technological process.

The third problem is precise adjustment of logs on the carriage. Adjustment as to the direction and angle of sawing, can be performed probably rather roughly, which means that the position of the log as to sawing optimization is greatly delicate. Namely, if we have accuratel measured and calculated relevant factors of optimal sawing, the tiniest deviation from the defined position of log on the carriage could then probably *CONSIDERABLY* disturb the expected result of sawing. Thus, if we are not able to adjust the log on the carriage precisely enough, all accurate measuring and great calculations make no sense.

These problems are theoretical and practically soluble with considerable investments. With an economical analysis that would give good results, and would present no obstacle for an optimization to be carried out in this way.

Apart from the problems of optimization of log yield as described above, there is another question which is for the conditions and way of further development of sawmilling in Yugoslavia very important - though not directly connected with the above described optimization. That is the fact that in our sawmills (especially with the technology of specified sawn elements) we must, beside achieving the maximum (or optimum) yield from each log, also try to produce the required assortment and quantity of sawn elements (dimension stock). Therefore we have made another approach to the question of an optimal sawing method, taking into consideration both maximum log yield and fullfilling the specification of sawn materials.

PROPOSED NEW APPROACH OF SAWING OPTIMIZATION

Since the approxiamtion at log form determination and sawing optimization cannot be avoided and there are no satisfactory data on the accuracy of these approximations, we think that it is nevertheless possible to assume that every log is a circular truncated cone. Although a truncated cone is a poorer description of a log than the one obtained by precise measurements, we should not expect poorer optimization results by using this form.

We shall describe a method which we consider theoretically appropriated, technologically possible and economically acceptable.

A log as a truncated cone is defined by three variables: d - thinner end diameter, D - thicker end diamter and L- length. Since the variables d, D and L can acquire only a final number of values and there is only a final number of logs, the problem of sawing optimization is discrete and final.

To every log T (d, D, L) is assigned m(d,D,L) different sawing methods R(d,D,L,r), (r=1,2,3, ..., m(d,D,L)).

Every sawing method results in a particular structure of logs S(d,D,L,r). To every log structure is assigned the volume (and/or value) utilization I(d,D,L,r).

$$\begin{tikzcd}
 & D(d,D,L,1) \arrow[r, Leftrightarrow] & S(d,D,L,1) \arrow[r, Leftrightarrow] & I(d,D,L,1) \\
 & \vdots & \vdots & \vdots \\
T(d,D,L) \arrow[ruu] \arrow[r] \arrow[rdd] & D(d,D,L,r) \arrow[r, Leftrightarrow] & S(d,D,L,r) \arrow[r, Leftrightarrow] & I(d,D,L,1) \\
 & \vdots & \vdots & \vdots \\
 & D(d,D,L,m) \arrow[r, Leftrightarrow] & S(d,D,L,m) \arrow[r, Leftrightarrow] & I(d,D,l,m)
\end{tikzcd}$$

Simulation of sawing enables determination of the values S(d,D,L,r) and I(d,D,L,r) for each pair of T(D,d,L), r(D,d,L.r) (HITREC 1980; 1981).

According to these results, a criterion analysis for log sorting is made possible (Hitrec, 1983; 1986).

Logs are sorted according to the criterion by which the logs of the same sawing method go into the according boxes.

It is important here to emphasize that our previous investigations (Hitrec, 1986) showed that - as sorting criteries- some other log characteristics (e.g. taper) on some occassions are more important factors than log diameter (which is as a rule considered dominant when sawing on frame saws).

Data T,R,S, and I will be stored in computer data file for optimization use. Every lumber specifications, either of a daily or long-term character, and knoledge of log dimensions on disposal, make possible optimization of log yield and satisfaction the required lumber specification. This can be done by linear programing (Kugler,1965).

The method is based on the following. The logs are sorted in groups. Each group and sawing method has its own known sawing lumber structure. The volume of logs in each group is likewise known. The specification defines the quantity and structure of the sawing lumber we wish to produce. The linear programing method determines the number of logs in a group to be sawn according to a particular schedule in order to satisfy the required lumber structure with the least possible log volume spent.

The mathematical model has been formed (Kugler 1965, Hitrec and others 1987) whereby the theoretical problem is solved.

The practical problem, however, is not so simple.

If a particular lumber specification contains the necessary proportion (or absolute quantity) of different lumber sizes, optimization by linear programing is carried out, and the result of sawing will be different from the calculated one. The reason for this is the log's deviation from the truncated cone form.

Logs from the groups of the calculted plan were chosen during the sawing process. The operator will try to saw according to the foreseen plan and to withdraw from it when he finds it necessary. This method certainly gave better results because, besides the worker's individual estimate, it also kept in mind the actual, objective calculations, such as choice of logs.

The difference between the planned and realized sawn wood specification can be reduced in the following way. The basic task can be divided in n not necessarily same current tasks. Optimization will be carried out in n-number of stages. The idea is to divide the basic sawing specification (desired strucure and number of sawn logs) into smaller parts, each with its own optimization and result control. Since the results will differ from the expected ones, each step can be followed by corrections. Such procedure is a relatively simple software and technological problem.

BT is the suposed basic task (assigment) to be realized (required lumber structure).

$$BT = R1 + R2 + R3 + \dots + Rn.$$

Let us introduce the following symbols:

CT(i) is the "current" task in the i-stage
P(i) is the sawing plan in the i-stage
S(i) is the assortment structure realized after the i-stage
d(i) is the difference between the required and assortment structure after the i-stage.

The procedure goes as follows:

In the first stage, CT(1)=R1, which results in P1 after

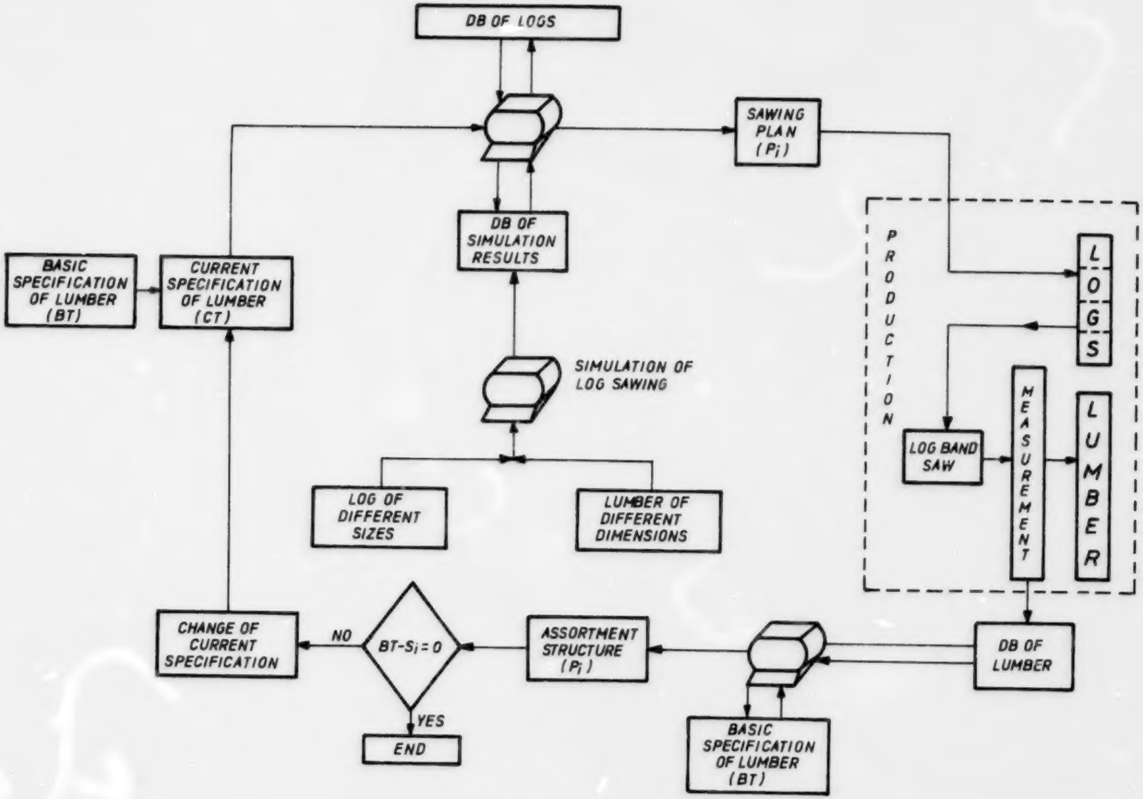
DB OF LOGS
SAWING PLAN (P_i)
DB OF SIMULATION RESULTS
BASIC SPECIFICATION OF LUMBER (BT)
CURRENT SPECIFICATION OF LUMBER (CT)
SIMULATION OF LOG SAWING
LOG OF DIFFERENT SIZES
LUMBER OF DIFFERENT DIMENSIONS
PRODUCTION
LOGS
LOG BAND SAW
MEASUREMENT
LUMBER
DB OF LUMBER
CHANGE OF CURRENT SPECIFICATION
NO
BT-S_i=0
YES
END
ASSORTMENT STRUCTURE (P_i)
BASIC SPECIFICATION OF LUMBER (BT)

FIGURE 1: ALGORITHM OF LOG SAWING OPTIMIZATION

optimization, and S1 after sawing. Owing to the difference between the supposed and actual log form, the difference is

$$d(1) = CT(1) - S(1).$$

Suppose that in the second stage

$$CT(2) = R(2) + d(1).$$

P(2) is calculated and after sawing, the result will be S(2)

The procedure is continued according to the algorithm:

$$CT(i) = Ri + d(i-1) \rightarrow P(i) \rightarrow S(i) \rightarrow d(i) = CT(i) - S(i)$$

The Algorithm is shown in Figure 1.

The model assumption is that d(n) becomes relatively small, if BT is big enough.

FINAL REMARK

Assumption that such aproach gives good results in optimization of sawing logs should certainly be checked experimentally. However, we think that the suggested method is probably better than the present one since, besides the experience of engineers and workers in sawmills, it also uses objective indicators.

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EXPERIENCES IN AIHIO SAWING

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SUMMARY

The method of AIHIO sawing has been under development in Finland throughout the 1980s. The starting point, and main aim, of the development has been the need for appropriate utilization of the raw material arriving at the saw mills. The paper deals with an integrated production model, in which the logs are utilized to yield both AIHIOS and traditional sawn timber. The machinery and production programs developed for the first integrated AIHIO saw have turned out to be proper. The results showed that the selection of raw material and a product range suited for it are key factors to success. The AIHIO process is under constant development and it will form one of the solutions in the efforts to improve the profitability of the traditional saw-mill industry.

INTRODUCTION

What is meant by AIHIO sawing and why the method has been developed

The AIHIO process has been under development in Finland throughout the 1980s. The starting point, and main aim, of the development has been the need for appropriate utilization of the raw material arriving at the saw mills. AIHIO sawing or AIHIO making thus refers to the production of parts needed by the end-users, e.g. window-makers, i.e. to the production of AIHIOs, instead of traditional sawn timber. The original, ambitious aim was a saw mill producing only AIHIOs needed by the customers through a careful selection of the logs to correspond to the quality requirements of the end-products. AIHIO making thus required, on the one hand, a certain customer-specific product range and, on the other hand, a supply of logs meeting the quality requirements of the AIHIOs to be produced. The move from traditional sawn-timber production to that of AIHIOs was based mainly on the advantages resulting for the customer, the wood-product industry. These advantages for the customer buying AIHIOs included, among other things the following:

- the exclusion of costs for the handling and drying of sawn timber;
- the possibility to dimension the products from their own needs and not from the standard dimensions of sawn timber;
- the amount of AIHIOs needed in production can be estimated in advance and their acquisition can be timed on the basis of the production;
- work methods can be simplified by using only AIHIOs of the right dimensions and quality;
- the flexibility of production and the profitability of short series are enhanced;
- a shortening of the periods of storage as well as those of production and delivery;
- a lesser need of production facilities.

AIHIO sawing models in practice

The path of the AIHIO sawing models from the planning stage to practice has been quite long. Several problems emerged at the very beginning to prevent an implementation of the original method. No solution was found for the problem of the inner-log quality measurement and the planning of the optimal AIHIOs based thereon. The undeterminacy of the customers and their product-range needs resulted in further problems for the planners as well. More difficult than was expected was also the introduction of the AIHIO idea to the companies mainly engaged in sawn-timber production. The research had centered mainly on the actual production of the AIHIOs themselves, and the raw-material flow was not complelety under control from the start of the production process to the production of the AIHIOs.

It was when the idea was being marketed that the need to produce traditional sawn timber alongside with the AIHIOs became evident. This joint production was seen to result in a higher yield in the form of a more efficient use of the fixed assets and the raw material and more balanced production. The first investments were therefore made in a saw mill which was modernized as an AIHIO mill. The aim was, alongside with traditional sawn timber, to produce AIHIOs at a minimum rate of 15 per cent of the total production volume, which was estimated as sufficient to make the production profitable.

The idea was to make the production of AIHIOs and sawn timber possible by using two basic models. In one of the models, the so-called AIHIO logs, i.e., raw material used only for AIHIO production, would be separated from the rest of the raw material at least at the sorting stage of the logs. The sawing processes for the AIHIOs and traditional timber would be separate.

The second model represents further integration, in that it would be possible to produce either sawn timber or AIHIOs from one and the same log. In principle, the heartwood would be used for sawn timber and the surface parts for AIHIOs. The first cleaving of the log would be done using different solutions depending on the outer quality assessment and the final production decisions would be made when reasonable certainty as to the inner quality of the log would exist. While making the decisions regarding the AIHIO production, it is possible also to specify the quality of the sawn timber in more detail and to avoid unmarketable sizes and especially to reduce the amount of chips.

The paper concentrates on results achieved with the second model.

AN INTEGRATED AIHIO SAWING MODEL

Handling of the log

In this production model, the main saws are band saws. Figure 1 exemplifies the main operating principles of the model. The raw material of the mill is subject to strict acquisition and dimensioning instructions and the raw-material storage thus contains only logs suitable for use at the mill. The unsorted debarked logs are first fed to the sawing line with a double band saw. The operator selects a quality criterion for the log from the following four alternatives:

Class I log: knotless on the surface
Class II log: small knots at the top
Class III log: vssible knots are sound
Class IV log: visible dead knots.

At the same time the log is positioned correctly for a measuring device located before the band saw. The device measures the outer dimensions of the log, thus yielding its top diameter, conicality and length. The measument and quality data determine the optimal sawing frame out of three possibilities: cleaving, splicing or balking (Figure 2). A control processor adjusts the blades of the band saw individually for each log as well as the sawing speed. The result is pieces shown in Fig. 2, named side blocks (2), center blocks (3) and balks (4). These are fed to the second operator, who determines the quality of each piece on the basis of the visible sawn surfaces. The pieces are measured with a measuring device, after which the information is put together and the computer feeds the blocks onwards in the process. As shown in model 1, the balks return to the double band saw, the side blocks go to the first rip saw and the center block goes to the edging saw.

The balks are handled with the alternatives shown in Figure 3: the double band saw or the cross-cutting saw. The cutting frame has been determined on the basis of the earlier measurement and quality data. The side blocks resulting from the first sawing of the balks move to the rip saw, and the other pieces go to sorting and loading.

The side blocks are sliced in accordance with block-specific measurement and quality data stored in the computer. This includes data for both cleaving and cross-cutting. A slice sawn from the side block goes to the edger. If a side block yields more than one slice, the remaining block goes to a block operator, who determines the quality of the side block and sends it to be measured. On the basis of this information, the sawing of the block is re-optimized and it goes back to the rip saw. This is repeated until all the slices have been sawn.

Handling of the slices and the center blocks on the edging line

The edging line consists of a measuring device and an edging saw. The pieces are fed automatically into a measuring device, and on the basis of the measurement results, the processor calculates the edging frame. After this, the piece is fed into the edging saw.

There are two ways of edging: normal edging and pre-edging. Pieces yielding sawn timber are edged in the normal way to correspond to standard requirements and the edged pieces are fed to dimentional sorting and on to various sawing treatments. Pieces to be moved to the AIHIO production are pre-edged, which means that their edging is limited to that required by their further treatment. There are two quality classes for slices going into the AIHIO production:

Class A: small, sound knots are allowed in the slices;
Class B: the slices may contain large sound and black knots.

The slices are sorted on the basis of their quality and thickness for sticking and drying.

THE AIHIO PROCESSING

The slices are taken to the AIHIO production when dried approximately to an 8-12 per cent moisture content. The main machinery of the AIHIO line consists of a measuring device, a cross-cutting saw, a rip saw and automated bar and cutting machines. The simplified process is exemplified in Figure 4.

Defects in the slices are marked manually on a longitudinal conveyor taking the slices to the measuring device, which records the defects, profile and length of the slice. A control processor finds the optimum product frame for the slice and determines the cutting points. Once cut, the dimensions of the pieces are checked, and the computer checks the earlier result, compares it with the new optimum frame and feeds the pieces in for cleaving.

After cleaving, the pieces go to the automated bar and cutting machines, which produce the final products in several stages. The products move on to the sorting line, where they are dropped to different slots depending on their length, width, thickness and quality.

EXPERIENCES WITH AIHIO SAWING

The results presented here are based on preliminary research, conducted when AIHIO sawing was first introduced. Therefore, the experiences and results do not as yet allow far-reaching conclusions on the new process. They do, however, show that AIHIO sawing is a production method well worth further development.

The raw material

The raw material delivered at the AIHIO sawmill did not meet the expectations or quality requirements set for it. This may have been due to insufficient instructions given to the logging department or their inexact implementation. In the dimensioning of the logs, enough information has to be available to determine the quality of the logs, especially with regard to the type and size of knots. Here we are dealing with problematics concerning insufficient identification of inner-log quality.

The quality assessment of the debarked logs admitted for sawing and the first sawing based thereon did not fully correspond to the quality expectations, either. The first sawing has a very significant effect on the success of the optimum raw-material yield. A continuous follow-up of the log quality and the quality of the sawn pieces may make it possible to give more exact instructions regarding the visual quality inspection of the logs.

Sawn timber and slices

The production of sawn timber was paid only casual attention to in the study. The volume and grade yield of the sawn timber corresponded well with the average sawing yield of the log quality.

The main purpose was to establish the value of the product yield obtained from the slices. Its value was compared with that of the sawn timber that could have been obtained from the logs selected for AIHIO production. The general quality of the slices, due to the raw material not meeting the quality requirements of the products, caused a loss in the yield. Problems were caused especially by knots and their quantity and quality. The short distances between the knots made it impossible to "pick out" suitable pieces between the knots. Even though for example sound knots could have been allowed, their sizes often proved unsuitable for the dimensions of the products. The conicality of the slices or the width of their rough edges resulted in excessive losses in the yield of AIHIOs, because the product range did not include one where rough edges could have been made efficient use of. In the handling of the slices, the quality was assessed only from the sawn edge, and because the quality of the end products is often determined on the basis of more than one edge, some of the edges could ultimately have unacceptable defects.

On the basis of preliminary calculations, it would seem that the value yield of the slices would have been higher in the form of traditional sawn timber than in the form of AIHIO products.

COMMENTS

The machinery designed for the AIHIO sawmill proved to be along the right tracks. The machinery and the programs designed for them worked reliably. The moving of the slices caused problems at places, due especially to the thin top parts of the surface slices and the curvedness of the dried slices.

An AIHIO sawmill requires a varied product range. Quality-wise, the products have to be correspond to the quality of both high- and low-class logs. However, the key factor is raw-material selection. In spite of variations in shape and quality, the raw material has to meet the quality requirements of the products chosen. The most important task of the industry is to produce goods by raising the value of the raw material while working at a high rate of raw-material yield.

The AIHIO method is under strong development and its has already proceeded to new implementation stages.

The AIHIO sawmill will be one of the solutions in the future struggle towards improving sawmills operating at a low level of profitability.

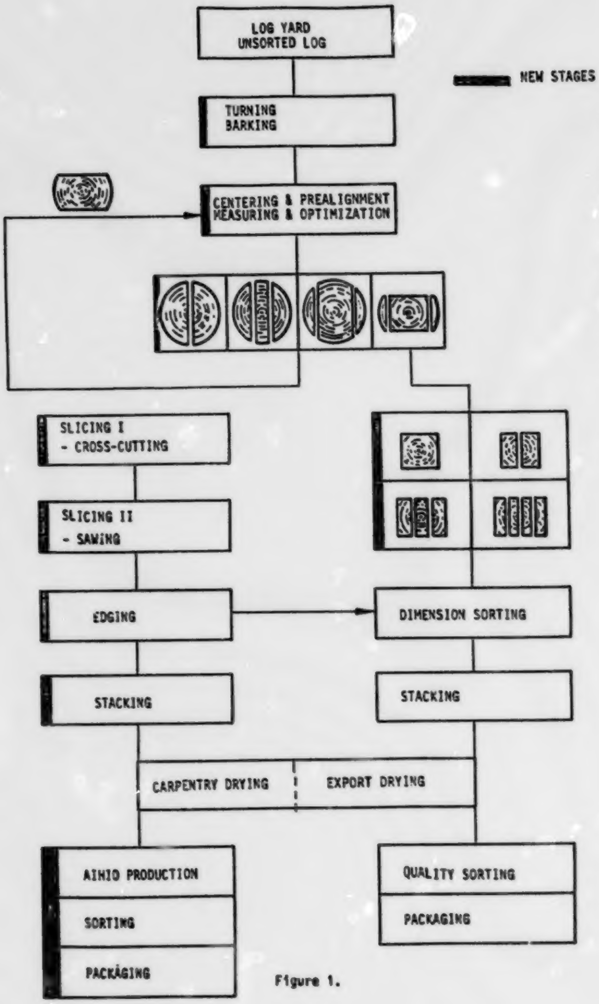
LOG YARD
UNSORTED LOG
NEW STAGES
TURNING
BARKING
CENTERING & PREALIGNMENT
MEASURING & OPTIMIZATION
SLICING I
- CROSS-CUTTING
SLICING II
- SAWING
EDGING
DIMENSION SORTING
STACKING
STACKING
CARPENTRY DRYING
EXPORT DRYING
AIHIO PRODUCTION
SORTING
PACKAGING
QUALITY SORTING
PACKAGING

Figure 1.

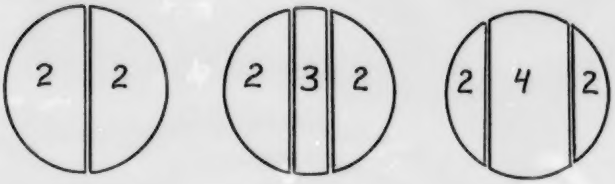

Figure 2. Alternative sawing frames

Names of the pieces:
2 side blocks
3 center blocks
4 balk

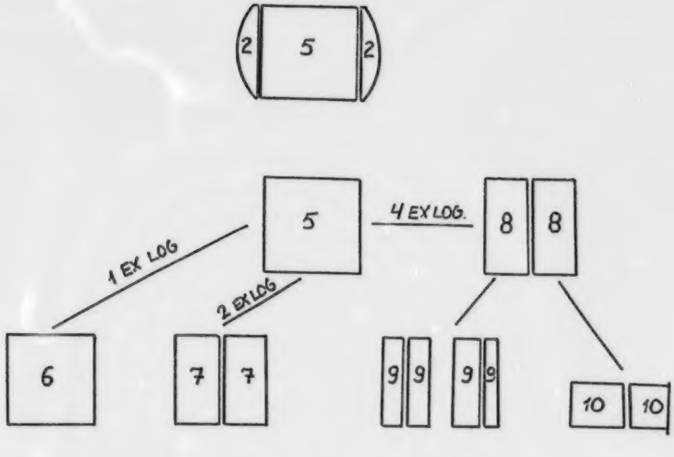
2
5
2
5
4 EX LOG.
8
8
1 EX LOG
2 EX LOG
6
7
7
9
9
9
9
10
10

Figure 3. Center block settings

Names of the pieces:
2 side blocks
3 center block
6 square block
7 center piece
8 center piece
9 4ex-log
10 horizontal 2ex-log

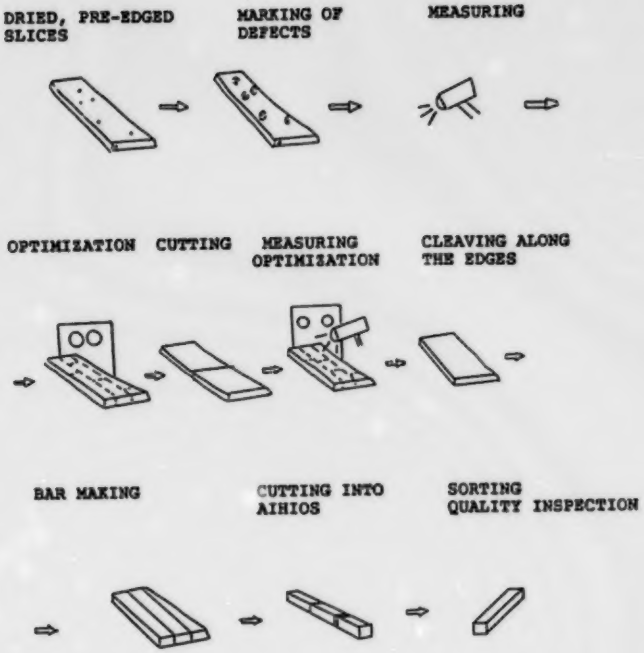
DRIED, PRE-EDGED SLICES
MARKING OF DEFECTS
MEASURING
OPTIMIZATION
CUTTING
MEASURING OPTIMIZATION
CLEAVING ALONG THE EDGES
BAR MAKING
CUTTING INTO AIHIOS
SORTING QUALITY INSPECTION

Figure 4. Raw-material flow in the AIHIO line

The main machinery of the AIHIO line include a measuring device, a cross-cutting saw, a rip saw and bar and cross-cutting automatons.

CONVERSION OF MIDDLE DIAMETER SUGI LOGS INTO SAWN LUMBER

-SAWING YIELD BY USING SAWING PATTERNS IN CONSIDERATION OF LOG QUALITY-

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FDC: 822: 853: 174.7 Cryptomeria japonica D. Don

SUMMARY

It is very important to use a sawing pattern considering not only end uses, sawing efficiency, and yield but also log quality in conversion of logs into sawn lumber. Until now we can find only few data on the lumber yield considering log quality. The lumber yield from the middle diameter sugi (*Cryptomeria japonica* D. Don) logs, one of the most popular planted species in Japan, were investigated using sawing patterns in consideration of log quality. The basic data was obtained for designing of high performance lumber manufacturing system.

Keywords: sawing pattern, sawing yield, log quality

INTRODUCTION

In Japan, the supply of the domestic planted coniferous species is expected to increase, since the most of them planted after World War II will reach the target age in the near future. Sugi (*Cryptomeria japonica* D. Don) is planted on the artificial forest of almost 45% and is dominant among the various species. Now, about 60% of sugi supply consists of the middle diameter logs and this tendency may continue at least for more than ten years. It is foreseen that the supply of high quality sugi logs will decrease and that of common quality logs will be dominant (Nishimura 1984 A). Since the sugi lumber from common quality logs has to compete with the imported lumber in price, the study of the lumber manufacturing system for the middle diameter sugi logs with common quality is required from a view point of low cost, less energy consumption, and high efficiency (Nishimura 1984 B).

When we convert logs into sawn lumber, we should use an optimal sawing pattern considering not only end uses, sawing efficiency, and yield but also log quality. The sawing patterns used in the various regions were reported (Konishi et al. 1979-1981). As for sawing the lumber used for package with a twin band saw machine, the effects of the sawing patterns on the yield were investigated (Nakata and Hirakawa 1987). However, there are few data on the lumber yield using the optimal sawing pattern in consideration of log quality.

Considering the above background, the middle diameter sugi logs were converted into sawn lumber using sawing patterns in consideration of log quality, and the sawing yield was examined in order to obtain the basic data for designing of high performance lumber manufacturing system.

EXPERIMENTAL METHOD

Two hundreds and seventy middle diameter sugi logs were supplied for this study from the private artificial forests. Top diameter range of them was 18-28 cm and length was 3.6 m or 4.0 m, according to Japanese Agricultural Standard (JAS). They were divided into two groups of 18-22 cm and 24-28 cm of top diameter. One hundred and fifty two logs were classified to one group (18-22 cm), and 118 logs were to another group (24-28 cm). Annual ring width, warp, location and size of knots on the log surfaces, and the other defects were measured after barking to grasp the quality of each log. Then all the logs were graded by JAS.

Two different machines, a band saw machine with carriage and a roller band resaw, were used to convert logs into sawn lumber. Band sawblades were of the standard types of shape for sugi logs. Sizes of sawblades were 152 mm in width, 1.05 mm in thickness, 35 mm in pitch, and 2.15 mm in kerf width for the former machine, and 127 mm, 0.90 mm, 32 mm, and 1.75 mm for the latter machine, respectively.

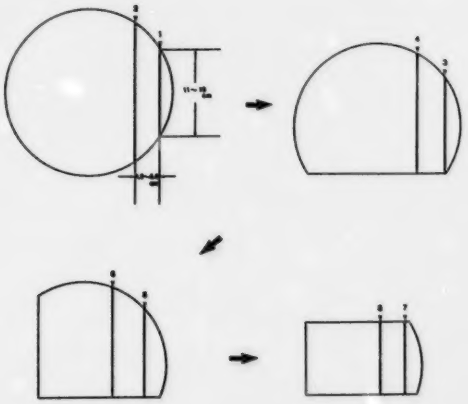

Fig. 1. Sawing order of around sawing.

Around sawing was basically used as the standard sawing pattern (Fig. 1). Sawing of each log was started at the best quality face. Sawing width was 11-13 cm at the first sawing. The second sawing was done after determination of thickness of the first lumber considering quality of sawn surface, log diameter, and location of the pith. Thereafter the log was turned and sawn in the same manner. Finally, a boxed-pith square was sawn. Sawing patterns modified of live sawing were also used depending upon the log quality. Seventy five sizes of lumber for construction members were sawn. The main sizes are summarized in Table 1. The lumber sizes with asterisk in Table 1 are only for "yakumono", specially high grade lumber for appearance use in interior of Japanese houses.

Table 1. Main sizes of lumber sawn.

Category	Lumber size (cm)			
Squareds	7.5X7.5	9.0X 9.0	10.5X10.5	12.0X12.0
Scantlings	2.1X3.0	3.0X 3.0*	3.0X10.5	3.6X 4.5
	4.5X4.5	4.5X10.5*	5.5X 5.5	5.5X12.0*
Boards	0.9X7.5-12.0		1.2X7.5-21.0	
	1.5X9.0-21.0		2.1X9.0-21.0	

*:only for "yakumono".

After all the sawn lumber was graded by JAS, both volume and value yields from each log were estimated by Equations (1) and (2), respectively. Log volume was calculated by Equation (3).

$$Y_{vol}=(\Sigma V_i)/V_0 \text{ X } 100 \qquad (1)$$

$$Y_{val}=\Sigma((V_i/V_o)\text{X}((P_i/P_o)\text{X}100)) \qquad (2)$$

$$V_o=d^2 \text{ X } 1 \text{ / } 10000 \qquad (3)$$

where, Y_{vol} is volume yield (%), Y_{val} is value yield (%), V_0 is log volume (m^3), V_i is each lumber volume (m^3), P_o is unit price of the standard lumber (yen/m^3), P_i is unit price of each lumber (yen/m^3), d is small top diameter of log (cm), and 1 is log length (m). The standard lumber is the First Grade (JAS) lumber of 10.5X10.5cmX3.65m which is the most popular post lumber in Japan. Average unit cost of this standard lumber is 56,000 yen/m^3.

RESULT AND DISCUSSION

Quality of Logs Used

Table 2 shows the log quality. The mean warp rates of 18-22 cm log group and 24-28 cm log group were 8.0% and 6.0%, respectively. The former is grater than the latter. This may be caused by the estimating method of warp rate. Because the warp rate is calculated as the ratio of the chord height of the warp to small top diameter, the warp rate of smaller log becomes greater than that of larger one, even if their chord height are same amount. Logs with the warp rate more than 15% had double warp, which appeared less than 10% of logs in the both groups. The mean taper degree of 18-22 cm log group was 1.2 cm/m, and that of 24-28 cm log group was 1.8 cm/m. Comparing with 18-22 cm log group, 24-28 cm log group contained more logs with the root swelling. Therefore, the taper degree of 24-28 cm log group was greater than that of 18-22 cm log group. Number of knots on the log surface was 14.4 (about 4 knots per 1 m in length) on the average in 18-22 cm log group. Average number of knots was 11.9 (about 3 knots per 1 m in length) in 24-28 cm log group. Rates of logs without knots were 21% in 18-22 cm log group and 30% in 24-28 cm log group. The larger diameter logs may have less knots on the log surface than the smaller diameter logs, since the the knots are involved inside the wood during the thickening growth after natural or artificial pruning. As the other defects, end check and ring shake were also measured. These defects did not influence on the log grade. There were few logs with remarkable insect holes or eccentric pith.

Table 2. The log quality.

Group / Item	18-22 cm		24-28 cm	
	Range	Mean	Range	Mean
Warp rate (%)	0- 35.5	8.0	0-40.0	6.0
Taper (cm/m)	0.3- 3.6	1.2	0.5- 4.4	1.8
Average annual ring width (mm)	1.3- 5.3	3.1	1.5- 5.7	3.2
Number of knots	0- 68	14.4	0-57	11.9
Average diameter of knots* (mm)	7.0- 80.0	27.3	12.3-80.0	28.4
Maximum diameter of knots* (mm)	7-150	44.6	13-143	51.2

*:Not include knot free logs whose numbers were 32 and 35 in 18-22 cm and 24-28 cm log groups, respectively.

Forty three, 102, and 7 logs in 18-22 cm log group were rated to the First, Second, and Third Grades according to JAS, respectively. On the other hand, 40, 82, and 5 logs in 24-28 cm log group were rated to the First, Second, and Third Grades, respectively. It is suggested that these grade compositions may reflect the present situation in the log market, because the most of them were purchased from the private log auctions without specifications for grade.

Sawing Patterns in Consideration of Log Quality and Sawing Yield

In general, "yakumono" is sawn from the better quality logs and "yakumono" output percentage influences on the value yield. Therefore, the logs were divided into three quality classes, Y, F, and W by "yakumono" output percentage instead of JAS in this study. "Yakumono" output percentages of Y, F, and W classes were more than 25%, 15-25%, and less than 15%, respectively. The examples of sawing patterns in consideration of log quality are shown in Figs. 2 to 9. In these figures, the bold lines indicate the sawing lines by the band saw machine with carriage, and the narrow lines indicate the sawing lines by the roller band resaw. The numerals indicate the consecutive sawing order by the band saw machine with carriage. The screen tone shows "yakumono" lumber. The sawing yields are obtained from the illustrated logs, and the percentages in the parentheses indicate the mean yields in each class.

Fig. 2 shows an example of the sawing patterns for Y class logs in 18-22 cm log group. Plural 4.5X10.5 cm "kamoi" were sawn from the outer portion of the log, and small sizes of "yakumono", such as "saobuchi" and/or "mawaribuchi", were sawn from the edge part of the flitches for "kamoi" as many as possible. The volume yield from this log was 60.2%, and the value yield from this log was 102.6%. Y class logs occupied 24.3% in 18-22 cm log group. The mean volume and value yields were 63.8% and 97.8%, respectively. Fig. 3 shows an example of the sawing patterns for F class logs in 18-22 cm log group. A piece of "kamoi" was sawn from the best quality log face, and scantlings and/or boards were sawn from the other faces. "Yakumono" output from this log was lower than that from the log illustrated in Fig. 2. Reflecting this, the value yield from this log was 73.8%, which was lower by about 25% less than that from Y class logs. The mean volume and value yields from F class logs in 18-22 cm log group were 60.4% and 72.5%, respectively. F class logs occupied 12.2% in 18-22 cm log group.

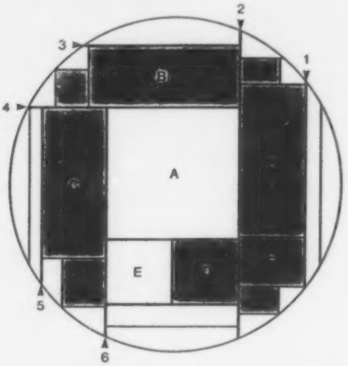

Fig. 2. An example of the sawing pattern for Y class logs in 18-22 cm log group.
Note: Volume yield: 60.2% (63.8%).
Value yield: 102.6% (97.8%).
A: 9.0X 9.0 First. B: 4.5X10.5 ▨.
C: 4.5X10.5 ◣. D: 4.5X 4.5 ◣.
E: 4.5X 4.5 First. F: 3.6X 4.5 ◣.

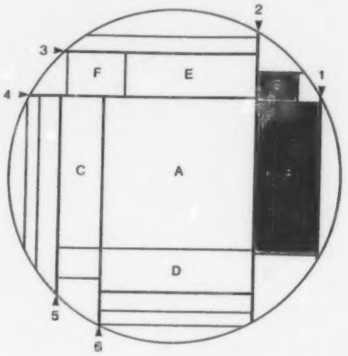

Fig. 3. An example of the sawing pattern for F class logs in 18-22 cm log group.
Note: Volume yield: 60.4% (60.4%).
Value yield: 73.8% (72.5%).
A: 10.5X10.5 First. B: 4.5X10.5 ▨.
C: 3.0X10.5 Special. D: 3.0X10.5 First.
E: 3.0X 9.0 Special. F: 3.0X 4.0 First.
G: 2.1X 3.0 ▨.

W class logs in 18-22 cm log group were sawn using three types of sawing pattern, which were named as Board Type (Fig. 4), Scantling Type (Fig. 5), and Combination Type (Fig. 6). Fig. 4 shows a modified live sawing. In Board Type, boards were sawn from the outer portion of the log, and

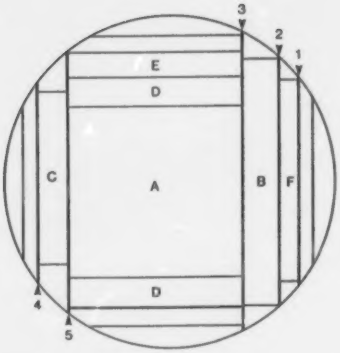

Fig. 4. An example of the sawing pattern for W class logs in 18-22 cm logs group (Board Type).

Note: Volume yield: 65.4% (62.6%).
Value yield: 60.4% (56.4%).

A: 10.5X10.5 First. B: 2.1X15.0 First.
C: 1.8X10.5 Special. D: 1.8X10.5 First.
E: 1.5X10.5 Special. F: 1.2X12.0 First.

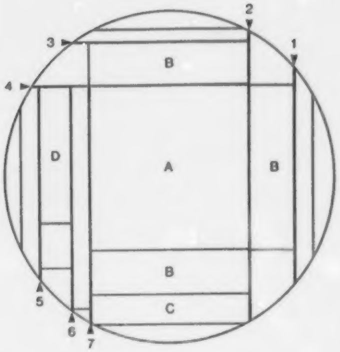

Fig. 5. An example of the sawing pattern for W class logs in 18-22 cm log group (Scantling Type).

Note: Volume yield: 60.7% (65.5%).
Value yield: 57.2% (57.9%).

A: 10.5x10.5 First. B: 3.0X10.5 First.
C: 2.1X 9.0 Special. D: 2.1X 9.0 First.

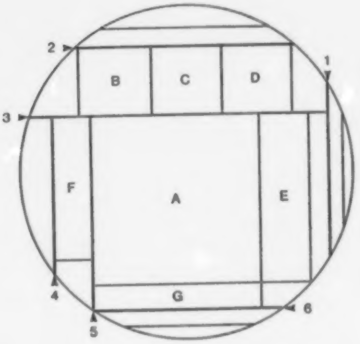

Fig. 6. An example of the sawing pattern for W class logs in 18-22 cm log group (Combination Type).

Note: Volume yield: 53.9% (63.4%).
Value yield: 59.7% (58.6%).

A: 10.5X10.5 First. B: 4.5X4.5 Special.
C: 4.5X 4.5 First. D: 4.5X4.5 Second.
E: 3.0X10.5 First. F: 2.1X9.0 Second.
G: 1.8X10.5 Second.

a boxed-pith square was sawn from the inner portion of the log. In Scantling Type, scantlings such as rafters and braces were sawn from the outer portion of the log. In Combination Type, boards or scantlings were sawn from the outer portion of the log considering defects appearance, location of pith, and so forth. The logs sawn using Board Type, Scantling Type, and Combination Type occupied 23.0%, 22.3%, and 18.2% in 18-22 cm log group, respectively. The mean volume yields using Board Type, Scantling Type, and Combination Type were 65.2%, 65.5%, and 63.4%, respectively. The mean value yields using Board Type, Scantling Type, and Combination Type from W class logs in 18-22 cm log group were 56.4%, 57.9%, and 58.6%, respectively. The mean value yields of W class logs were significantly low compared with those of Y and F classes logs. There were little differences in the mean volume and value yields from W class logs in 18-22 cm log group even if the logs were sawn using different types of sawing patterns. Therefore, it seems better to choose one of the above three types of sawing pattern as to the conversion of W class logs in 18-22cm log group into sawn lumber, depending upon the production strategy.

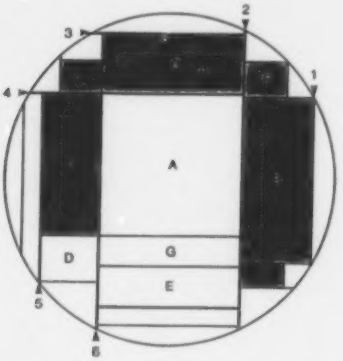

Fig. 7. An example of the sawing pattern for Y class logs in 24-28 cm log group.
Note: Volume yield: 67.9% (64.1%).
Value yield: 101.6% (94.9%).
A: 10.5X10.5 First. B: 5.5X12.0 [illegible].
C: 4.5X 4.5 [illegible]. D: 4.5X 4.5 First.
E: 3.0X10.5 First. F: 3.0X 3.0 [illegible].
G: 2.1X10.5 First.

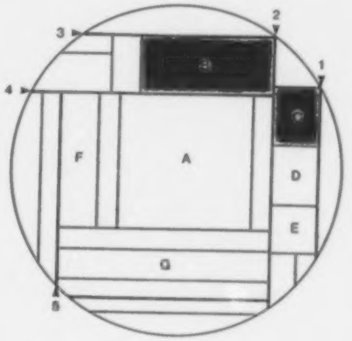

Fig. 8. An example of the sawing pattern for F class logs in 24-28 cm log group.
Note: Volume yield: 63.1% (60.6%).
Value yield: 75.4% (69.7%).
A: 10.5X10.5 First. B: 4.5X10.5 [illegible].
C: 3.6X 4.5 [illegible]. D: 3.6X 4.5 First.
E: 3.6X 3.6 Special. F: 3.0X10.5 First.
G: 2.4X15.0 First.

Fig. 7 shows an example of the sawing patterns for Y class logs in 24-28 cm log group. Plural "kamoi" were sawn prior to the other kinds of lumber from outer portion of the log in the same way as Y class logs in 18-22 cm log group. However, compared with Y class logs in 18-22 cm log group, larger sizes of "yakumono" could be sawn and "yakumono" output from Y class logs in 24-28 cm log group was greater, because their diameters were larger. Y class logs occupied 45.8% in 24-28 cm log group. The mean volume and value yields from them were 64.1% and 94.9%, respectively. A piece of "kamoi" was sawn from the best quality log face of each F class log in 24-28 cm log group in the same manner as F class logs in 18-22 cm log group (Fig. 8). The mean volume and value yields from F class logs in 24-28 cm log group were 60.6%,

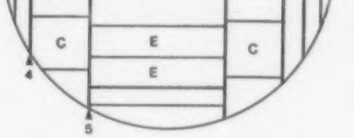

Fig. 9. An example of the sawing pattern for W class logs in 24-28 cm log group.
Note: Volume yield: 68.4% (65.2%).
Value yield: 58.9% (58.4%).
A: 10.5X10.5 First. B: 4.5X 4.5 First.
C: 4.5X 4.5 Second. D: 2.1X10.5 First.
E: 2.1X10.5 Second.

69.7%, respectively. F class logs occupied 16.1% in 24-28 cm log group. Fig. 9 shows an example of sawing patterns for W class logs in 24-28 cm log group. W class logs in 24-28 cm log group were sawn using the same three types of sawing pattern as those used for W class logs in 18-22 cm log group. An example of the sawing patterns for W class logs in 24-28 cm log group is shown in this case, since there were little differences in the sawing yields among three types of sawing patterns. This example is also modified live sawing. W class logs occupied 38.1% in 24-28 cm log group. The mean volume and value yields from these logs were almost on the same levels as those from W class log in 18-22 cm log group, and were 65.2% and 58.4,% respectively.

Influences of Knots on the Log Surface on Sawing Yield

Fig. 10 shows relationships between number of knots on the log surface and volume yield. The volume yield are almost on the same level at any range of number of knots on the log surface. Fig. 11 shows relationships between number of knots on the log surface and value yield. The value yields decrease with an increase in number of knots on the log surface in both cases of 18-22 cm and 24-28 cm log groups. This decreasing rate tends to become lower with an increase in number of knots on the log surface. The value yields from 24-28 cm log group were higher than those from 18-22 cm log group at any range of number of knots on the log surface.

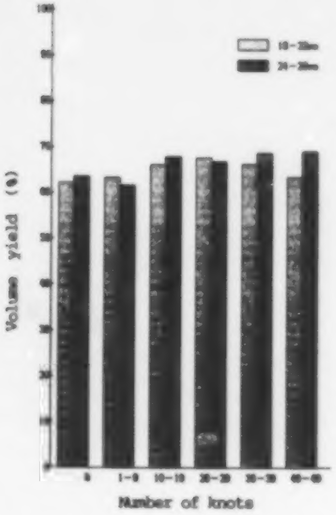

Fig. 10. Relationships between number of knots on the log surface and volume yield.

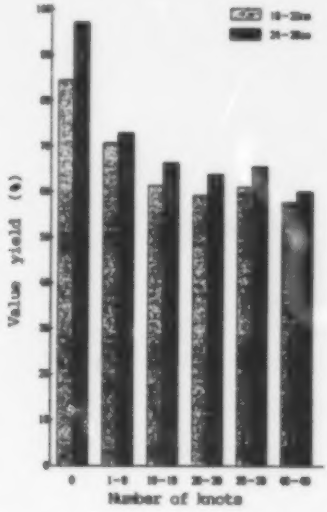

Fig. 11. Relationships between number of knots on the log surface and value yield.

The value yields are summarized in Table 3 depending upon the appearing patterns of knots on the log surface when the log surface is divided into four log faces. This table reveals that significantly high value yield is expected from the higher quality logs with adjacent two or more clear log faces. On the other hand, higher value yield can not be expected from the lower logs with only one clear log face or no clear face. Resulting from this fact, the sawing pattern aiming at the value yield is better to be applied for the high quality logs with adjacent two or more clear faces, and the sawing patterns aiming at the sawing efficiency for the low quality logs. Judging from the relatively large standard deviations of value yield from the logs with adjacent two or more clear faces, it seems that skill in decision making concerning sawing pattern greatly influences on the value yield.

Table 3. The value yield depending upon the appearing pattern of knots.

Diameter / Pattern	18-22 cm			24-28 cm		
	Num.	Mean	St. dev.	Num.	Mean	St. dev.
Four faces clear	32	84.5	23.7	35	97.2	27.4
Three faces clear	28	73.9	24.8	19	74.2	21.3
Adjacent two faces clear	17	78.1	23.7	15	74.1	14.8
A face clear	20	56.7	6.4	19	68.4	13.6
No face clear	54	60.2	8.9	29	61.7	7.3

CONCLUSIONS

In this study, the logs were classified into three quality classes of Y, F, and W by "yakumono" output percentage, and the differences in the mean volume yield were not evident among three classes. On the other hand, there were significant differences in the mean value yield among them. The mean value yields from Y, F, W classes attained to 95%, 70%, and less than 60%, respectively. More than 75% of value yield is expected from higher quality logs with adjacent two or more clear log faces. However, it is difficult to obtain high value yield from the lower quality logs. This fact may be one of the effective indicators for selecting sawing patterns on the standpoint from the value yield or the sawing efficiency.

The basic data will be obtained for patternizing of sawing method in consideration of log quality, computer aided automatic log converting systems, and designing of efficient production lines in lumber manufacturing.

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CAPTURING DATA FOR THE SAWMILL COMPUTER SYSTEM

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SUMMARY

As computer systems are becoming common in the wood industry, the problem of integrating different systems is accentuated. Recent experiences from the Norwegian sawmilling industry are the background for this discussion. Possibilities with respect to integrating computer systems from different manufacturers into one overall information network is the topic of the paper. Standardizing information is argued to be not a hindrance to further development, but a necessary basis for it. Only the users can form a platform for specifying their needs in this respect. And only the users have the capability to enforce such a standard.

Keywords: Material & Production Management, Information Technology, Computer Science, Wood Machining.

INTRODUCTION

During the last few decades the sawmilling industry has become a highly automated activity. The productivity of one worker has increased 10-folds in the last 20 years. From the increased efficiency follows that any worker today has the capability of producing a blunder that would need an engineer only a couple of decades ago! This very simple fact should make the industry aware of the necessity of providing each worker with sufficient and up to date information.

The same increase in productivity has not taken place in the managing process. Although computers have taken over a number of "bread and butter" routines, the overall system show signs of stagnation. A study in Norwegian sawmills (1989) show that most of the mills use computerized systems for accounting, payrolls and, to some extent, inventory control. A similar study from 1986 (Garnæs) gave more or less the same result. It is tempting to conclude that the sawmills use computers to keep down the cost of maintaining an out-dated management system.

In order to see some real pay-back from the computer systems it would appear to be necessary not only to automate old routines, but even to find some way of utilizing the full potential of the computers themselves and the data that is captured by computers all over the sawmill.

The material in this paper is based on experiences from a project in the field of MPM (material & production management) in the Norwegian Institute of Wood Technology. The project is organized with a group of 10 sawmills, 4 computer manufacturers and the institute. Some of the sawmills are working on pilot-projects that are reported back to the group. This gives the group access to the generated know-how. In addition to this we are working on a number of smaller studies in topics of mutual interest such as:

- Compiling experiences with automated data capture from production processes.
- Standardizing electronic "documents" to ensure a seamless integration of computers from different makers.
- Standardizing article numbering and bar-code for internal use in the sawmills.

Since we work as consultants in the industry our results are not based on scientifically verifiable experiments. Working in full-scale production the cost of that would obviously be prohibitive.

MATERIAL AND PRODUCTION MANAGEMENT

We are used to thinking that only managers make decisions in the industry, although the big volume of decisions are made at floor level: Sorters make 10 to 20 decisions every minute of the day. A sales representative makes from 20 to 100 decisions a day. Decision-making at these levels are based on knowledge and information. Although the decisions are not all that complex, they will be part of the overall business result. One of the tasks of a material and production management (MPM) system is to provide these people with the information they need in their daily work.

For a computerized MPM-system this involves converting information from digital signals to signals or paper documents that can be interpreted by humans with different abilities and background. The task is completed only when the information is understood.

Figure 1 is a block diagram of a model MPM-system that gives an overview of such systems. It consists of five layers of independent modules. Each layer has its own scope of work, and it is preferable that modules does not span several layers.

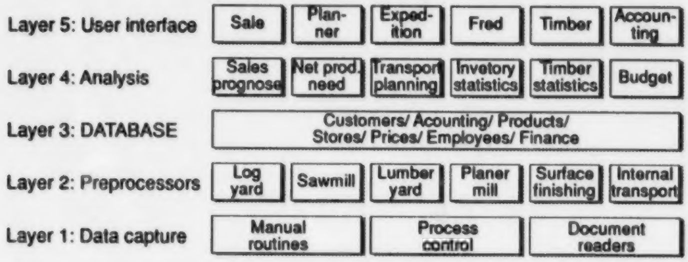

Layer 5: User interface
Sale
Planner
Expedition
Fred
Timber
Accounting
Layer 4: Analysis
Sales prognose
Net prod. need
Transport planning
Invetory statistics
Timber statistics
Budget
Layer 3: DATABASE
Customers/ Acounting/ Products/ Stores/ Prices/ Employees/ Finance
Layer 2: Preprocessors
Log yard
Sawmill
Lumber yard
Planer mill
Surface finishing
Internal transport
Layer 1: Data capture
Manual routines
Process control
Document readers

Figure 1: Block diagram showing the general topology of the MPM-model.

- Layer 5: User interface consists of routines directly communicating with different users. It is the top level of the system, and preferably the only part of the system directly visible to the users. By separating these routines from the rest of the system, it is possible to keep the system adaptable to changing needs. This layer should be user specified and adapted to the needs of the individual sawmill. The figure shows one module with the name "Fred", indicating that key personnel should be given special implementations fitting their needs.

- Layer 4: Analysis. This layer consists of common tools used to implement the modules of the next layer. Tools like sales prognostication, transport planning, inventory statistics and budgets are used by several of the top level routines. By separating them out in one layer it is possible to implement routines that may be re-used in several mills. Thereby the cost of the system can be kept to a minimum.

- Layer 3: Database. All the information in the system is stored in a database. This layer also contains routines for loading data into and reading data from the database, as well as general householding routines. The layer should be implemented by one manufacturer and reside on one computer in order to maintain the integrity of the data.

- Layer 2: Preprocessors. As we shall see, the problem of getting information into the database is not lack of data, but an excess of it. The preprocessors are software and hardware units that extract useful information from the collected data before it is sent to the database. All routines for screening and uploading data to the database, reside in this layer.

- Layer 1: Data capture. Modules for controlling the hard work of capturing data are located in this layer.

The goal of the MPM-system is:

"To provide any employee with access to all the information he or she needs in order to be able to make sound decisions."

To achieve that goal, the following sub-goals must be fulfilled:

Information Must Be Correct.

If a person is making a decision and some piece of information is lacking, that information will be substituted for a value based on experience and the decision will normally prove to be fairly close to optimum. If the information is present but incorrect, the decision will most probably be in error. Lack of information is inconvenient, wrong information is dangerous!

The most common cause of error in computer-based information is typing mistakes from manual input, loss of integrity caused by data conflicts and loss of data in transfer from other computer systems. In one of our pilot-sawmills, we had, according to the computer system, 11% imbalance in the overall volume checksum. That meant that 11% of the goods produced had simply "gone astray" somewhere in the lumber yard. Most of this were found to be caused by typing mistakes.

Information Must Be Relevant.

It is a common problem with computers that they produce irrelevant information. Systems that unloads all known information about a topic for every request are simple to implement because the programmer does not need to take into account what information is relevant to the user. Since most programs have been specified and implemented by computer experts, simplicity in implementation is normally an over-emphasized design criterion.

Information Must Be Understandable

It is self-evident that information is useful only to the extent that it is understood. Present-day computer-systems do not aid people in this respect. Therefore it is necessary to take a look at what is needed to feed people with understandable information.

Studies in psychology, sociology and perception physics are combined in the field called ergonomics. A prototype developed last year along ergonomic principles show that the quality of computer systems can be greatly increased.

CAPTURING DATA FOR THE MPM-SYSTEM

Operating principles for data capturing computers.

Most of the data needed for the MPM-system are available in the process control equipment scattered around in the mill. What is not already there must be provided in some way or other. The possible sources of information can be divided into four classes depending on their current representation:

- Written documents, human-based information.
- Computer-readable documents. (Bar-code, magnetic media etc.)
- Digital information. (Already in a computer.)
- Physical quantities. (Dimension, temperature, time etc.)

In most practical cases physical quantities can be measured by electronic instruments and converted into digital signals. This class will not be described further.

Human-Based Information

Information that resides in the human brain must necessarily be input to the system manually. At present stage of development this is also true about most printed and hand-written documents. Although character recognition is making rapid progress, the error rate is still too high to make it interesting for our purposes.

Manual input of information is known to cause errors. It is necessary to screen the input rigorously for possible conflicts and warn the user about them. To achieve this, knowledge about the process in question and about other data already existing in the system must be used in the screening process.

Some examples: The volume coming out of a process must be smaller than what is registered into it. The wood species must be the same on input and output. The contents of a delivery must match the order. I could go on forever.

To build a good screening system the programmer must have access to knowledge about the practical task at hand. This can only be provided by the user.

Computer-Readable Documents

Printed bar-code and documents stored on magnetic media are examples of computer-readable documents. The task of reading such information is technically straight forward. The task of interpreting the document is quite another matter. The document consists of a long string of binary code, and a key to decode it is necessary. This key should be standardized in such a way that the information means the same no matter what computer receives it. Bar-codes are already standardized, and the only remaining problem is to decide which standard to use.

Digital Information.

This information should be the simplest to get access to. Alas, that is not the case. Computer manufacturers are traditionally very protective about the communication protocols in their systems. This is the main problem in integrating the information flow in the sawmill. What is required to break this dead-lock is for the users to demand that systems are inter-connectable. No communication, NO SALE!

Fortunately international standards are underway. The next couple of years should bring this work to completion. The model called Open Systems Interconnect is becoming an ISO standard. As long as this standard only controls how systems communicate, it is not a hindrance to developing more efficient computers. It is probably a requirement for creating them.

Standardizing electronic documents.

From information theory we know there are three levels of a message: The outer message that tells us to expect to find information in an object. Examples may be the shape of objects, like in a book or a stone plaque. The next level of the message is the key to decoding the information. For printed documents this is solved by teaching children the ability to read. This is where strict standardization comes into play. The last level to a message is the actual information contained in the object like the printed letters in a book or the hieroglyphs of a stone plaque.

The same levels can be found in computer-based information. The dimensions and contrast level of bar-codes and the polarization in magnetic media is the outer layer of the message telling the computer that the signals it receives is information rather than electric noise.

The key to decoding the information is contained in standards. The ASCII character set being the most basic. (ASCII: American Standard Code for Information Interchange.) But further standardization is necessary in order to decode the information. This would typically consist of an agreement between manufacturers and users on how documents should be represented.

A natural starting point would be the ASCII character set which is well established. Using that character set we might expect to find something like this in the information flow:

```
....
....
MESSAGE ENDS
[ESC]MPMAIN,WOOD LOG DESCRIPTOR. VER-001
S=LOGSORT,
P RADIATA,CL=0492,
TD=021,TA=008,LN=45,OV=083,HP=043,HS=009
MESSAGE ENDS
[ESC]PLANER,WOOD PACKAGE DESCRIPTOR. VER-003
....
....
```

Figure 2: Standard electronic document in a continuous data flow.

Each message starts with the special character [ESC] (= ASCII value 27) and an opening message. This is the key to decoding the rest of the information. The opening message consist of a receiver address, "MPMAIN". Then that this has something to do with "WOOD" and that it is in fact a description of the log that follows the version 001 of the standard. The next three lines reads as this:

- S=LOGSORT : The sender.
- P RADIATA : Species.
- CL=0492 : Norwegian class 2.
- TD=21 : Top diameter, 21 cm.
- TA=8 : Taper, 0.8 mm/m.
- LN=45 : Length, 45 dm.
- OV=83 : Ovality, 83%.
- HP=43 : Hook position 43% form top.
- HS=49 : Hook size, 49 mm

A standard document really is that simple! The main problem is getting together and deciding what principles the standard should follow and who is to decide the actual shape of each document. The Norwegian Institute of Wood Technology has just started working on such a standard. More results should be available at the congress.

The Data Capture Workstation.

The hardware needed to capture data might typically look like figure 3. A micro-computer is used to collect data from a wide variety of sources connected to a local area network. The information flow in the network should be standardized and independent of manufacturers. The micro is connected to the main MPM-computer by way of a modem or a commercially available network.

The local processing capacity is used to preprocess the data collected, and to administer the flow of data. From the total data volume a local report is compiled and printed. Most of the data is interesting at the local level where it is possible to act on it.

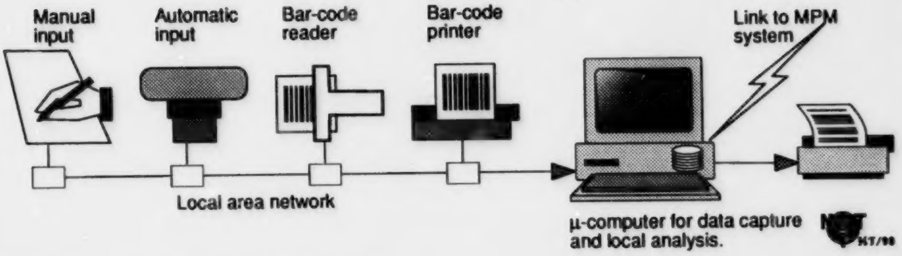


Figure 3: Data Capture Hardware

It is tempting but unwise to use detailed data to watch over the performance of individual employees. That would weaken the motivation of the employees to collecting the data. Without such motivation the data will be inconsistent and the MPM-system will ultimately break down.

The micro-computer compresses data into the minimum required by the MPM-system, and sends it over in a standardized form. For the moment we work on the assumption that the micro-computer in question is an IBM-PC-compatible computer running MS-DOS operating system. As a basis for a standard this is not wise in the long run, but as a starting point it is sufficient. Each manufacturer then faces the problem of connecting their equipment either to the PC directly or to one of the networks in the system. This is far simpler than connecting to the wide variety of computers that coexist in one sawmill.

CAPTURING DATA FROM EXISTING PROCESSES.

In our sawmills, planer-mills and sorters there is a large number of different systems that make measurements in order to control the processes. A brief description of the possibilities that present themselves in the sawmill alone should indicate the value of these data. Figure 4 shows a sawmill layout with process control equipment marked out. Table 1 is a list of the data available in the lay-out, what it is used for what use the MPM-system can make of it.

The sawmill is fairly typical for medium-sized Scandinavian mills. It consists of a log haul deck, a quad band-saw with chippers, a multippel circular saw with chippers and an edger. The lumber is then fed to a sorter and from there to the stacker. A total of 4 operators are indicated. The capacity of such a lay-out would be 100 - 120 000 m^3 timber per year running one shift.

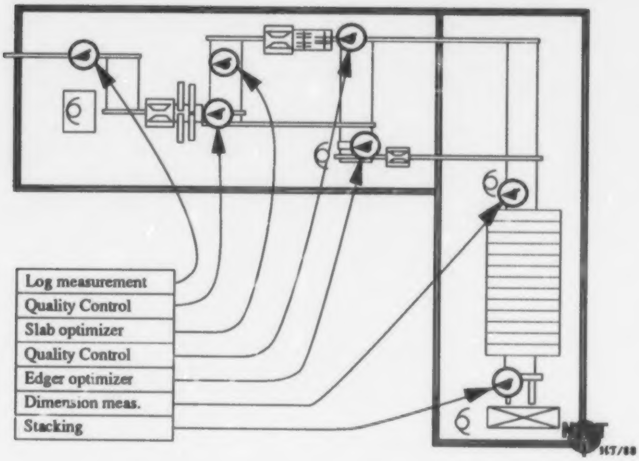


Figure 4: Process control equipment in the sawmill. (Garnæs, Nordby, Toverød, 1989)

Table 1: Information available in the sawmill.

MEASUREMENT	PARAMETER	MAIN USE	INFO. VOLUME	SECONDARY USE	2. VOLUME
Log measurement	3 diameters at 10 cm interval	Calculating best cutting pattern.	280 bytes	Timber inventory Timber statistics	12 bytes
QC 1. saw	Board thickness Slab height	Sawing accuracy	800 bytes	Quality documentation	6 bytes
Slab optim.	Slab height Edge position Fault detection	Calculating best cutting pattern	2000 bytes	None?	
QC 2. saw	Plank thickness	Sawing accuracy	1600 bytes	Quality documentation	12 bytes
Edger optim.	Board thickness Edge position Fault detection	Calculating best cutting pattern	3000 bytes	None?	
mension	Length per piece	Prod. statistics Dimension sorting	4 bytes	Yield	1 byte
Packaging	Package content	Inventory	2 bytes	Lumber inventory	2 bytes
			7686 bytes per log		33 bytes per log

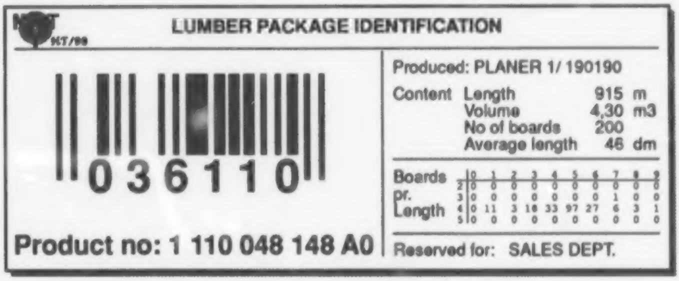
The "INFO. VOLUME" is an indicator only, and will wary with log size and the actual brand of equipment. One might be tempted to send all the available information to the MPM-database. This is not recommended. The volumes of information is too high. With 7,5 kB per log, the system would use 7 seconds to transfer the data over one normal terminal line. In that time the next log is half finished! (1 kB - 1024 bytes amounts to half the page you are currently reading.) Apart from this, the full information volume is not needed in the main system. Therefore it is not wanted. The column "secondary use" and "2.volume" indicates the information needed in the MPM-system.

Each log is described at most by its diameter, taper, length, ovality, hook position and hook size. The main use for these data is to keep the inventory of timber up to date. It is also possible to build a good statistical database for simulation purposes. This is vital to the production planner.

Quality documentation is useful to the planner. By this it is possible to gain more knowledge of the future raw-material for secondary breakdown processes.

Dimension measurement coupled to timber intake volume gives recovery directly.

Package specifications are conveyed as is to the MPM-system for inventory control, and the package itself is marked with a package specification and identification as shown in the figure below.



LUMBER PACKAGE IDENTIFICATION

036110

Product no: 1 110 048 148 A0

Produced: PLANER 1/ 190190

Content	Length	915	m
	Volume	4,30	m3
	No of boards	200	
	Average length	46	dm

Boards pr. Length

	0	1	2	3	4	5	6	7	8	9
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	1	0	0
4	0	11	3	18	33	97	27	6	3	1
5	0	0	0	0	0	0	0	0	0	0

Reserved for: SALES DEPT.

Figure 5: Lumber package identification.

The most important aspect of that document is its package number which must be unique among all the packages in the inventory. By providing the package with a bar-code version if its ID-number it is possible to re-use the electronic form of the specification stored in the database.

A Practical Case.

Leaving the details we will now take a look at how the system was configured for one particular sawmill. The process layout is shown in figure 6, and the points of measurement are marked with symbols.

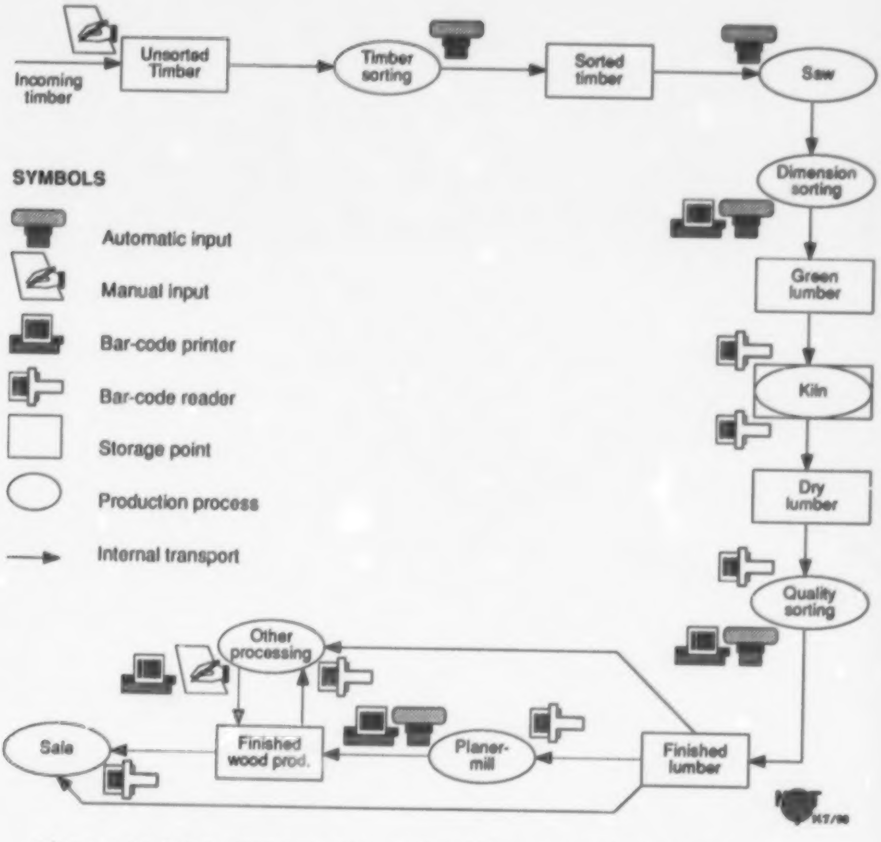

Incoming timber
Unsorted Timber
Timber sorting
Sorted timber
Saw
Dimension sorting
Green lumber
Kiln
Dry lumber
Quality sorting
Finished lumber
Planer-mill
Finished wood prod.
Other processing
Sale
SYMBOLS
Automatic input
Manual input
Bar-code printer
Bar-code reader
Storage point
Production process
Internal transport

Figure 6: Data capture for controlling material flow in a sawmill.

The use of data from each point is listed in the table 2. The total flow of wood materials from one inventory level to another is captured in this system. From that it is possible to make reasonably accurate assessments of the economic recovery of the different processes.

Table 2: Use of captured data.

MEASUREMENT POINT	COMMENT	USE OF THE DATA
Incoming timber	Manual registration from transport documents.	+ Timber inventory.
Timber sorting	Automatic sampling form existing log measurement system.	- Timber inventory. + Sorted timber inventory.
Log haul	Automatic sampling from primary break-down optimizer.	- Sorted timber inventory. + Sawmill raw material.
Lumber sorting	Auto. read-in from stacker controller. Bar-code ID on packages.	+ Green lumber inventory. Economic recovery.
Kiln in	Bar-code reader.	- Green lumber inventory. + Kiln. Specification for kiln controller.
Kiln out	Bar-code reader.	- Kiln. + Dry, unsorted lumber.
Quality sorting in	Bar-code reader.	- Dry, unsorted lumber.
Quality sorting out	From stacker. Bar-code ID on packages.	+ Finished lumber. Economic recovery and Quality statistics.
Planer-mill in	Bar-code reader.	- Finished lumber. + Raw material planer.
Planer-mill out	From stacker. Bar-code ID on packages.	+ Finished wood product. Economic recovery planer.
Other processing in	Bar-code reader.	- Finished wood product. + Raw material other proc.
Other processing out	From stacker. Bar-code ID on packages.	+ Finished product. Economic recovery.
Sale	Bar-code reader.	- Finished lumber or wood product. Sales documents. Invoice.

The impact of a bar-code system is most easily seen in the material flow from dimension sorting to quality sorting. Here the data printed at the stacker is re-used 3 times before the package is broken up.

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Today's Forest Management Practices Influence the Timber Quality of tomorrow

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FDC: 815: 232.43: 176.1 Quercus robur L.

Background: The dominant objective of traditional Forest Management is to maximise the quantity of timber to be produced on a given area within a limited time. Afforestations especially in the subtropics and the southern hemisphere with fast growing species (Eucalyptus, Southern Pines) lead to a substancial world wide growth of wood supply. For regions which are not favoured by climate and/or favourable economic conditions (low costs for labour and land) it is difficult to meet this challenge on the world market. On the other hand the demand for quality timber is rising. Therefore especially industrialized countries with moderate climate conditions think about changing there Forest Management Practice towards a quality orientated forest production. In that context informations and results about the correlation between silvicultural treatment and wood quality are urgently needed.

Basic variables: Silvicultural treatment can be varied by initial spacing of planting, thinning patterns, fertilizing and artificial pruning (independent variables). Important primary quality parameters are wood density, width and structure of the annual rings, shape of the log (crookedness, conicity), branches, knots. These factors influence secondary quality parameters, i.e. physical strength, visual quality, yield in the mechanical and chemical process (dependent variables).

Methods: To get valid informations about the correlation between silvicultural treatment and wood quality, it is necessary to find and compare stands the treatment of which is significantly different and has been reported exactly throughout the decades. Especially for natural regenerated broad-leave stands it is very difficult to find these examples. The well established network of experimental plots which has been installed in former times for the development of yield tables in Central Europe, especially in Germany, give us now the possibility to do also quality orientated research.

Example: Two different stands of oak (Quercus robur) situated in the Spessart region, well known for its first-class veneer and timber, were compared. Both are about 110 years old, stand 1 has been natural regenerated as it is typical for the former and the recent management practice. Stand 2 has been artificially created on former agricultural land by sowing in rows with 4 meters distance.
Site-class, climate and other growing conditions were comparable.
For our investigations we took a sample of 15 stems from each stand and compared the following variables: Dimension of the tree; crookedness; thickness of the bark; number distribution and a diameter of branches water sprouts, burls and knots; proportion and eccentricity of the core and other defects.

After that the trees were transported to the sawmill and scaled into three logs of five-meter length each. The logs were classified according their quality following the German classifying system HKS. Out of these logs boards were produced (log 1: 40 mm, log 2 and 3: 30 mm thickness, a total of 500 boards.

For the sawn timber again the dimension (volume) and a set of quality describing parameters was measured i.e. knots, width of annual rings, cracks. All the boards were classified according to the two german grading rules for sawn timber (Tegernseer Gebräuche, DIN 68 370). In addition to that, for a sample of clear specimen the width and proportion of early wood and late wood within the annual rings, the wood density and parameters for physical strength (bending, crushing, modul of elasticity shock resistance) had been tested according to the German DIN 52 180 ff.

Results: The first important result was the different dimension of the logs produced within approximately the same time (110 years). The average diameter of stand 1 (natural regeneration) was 35 cm DBH, stand 2 (line sowing) 38 cm DBH. Result of that higher increment was both significantly higher log volume (stand 2: + 18 %) and output of sawn timber (stand 2: + 10 %).

Regarding the quality of round wood stand 2 had better results for log 1 and 2 of every tree, only log 3 (upper part of the tree) showed significant more and bigger branches. Also the quality of the sawn timber of stand 2 was significantly better; mostly an effect of the quicker callousing of the branches caused by the better radial growth. Density, width of annual rings and proportion of early wood and late wood within the ring - all effecting the veneer quality - were not significantly different between the two stands and there was no significant difference in strength properties of the two samples.

Conclusion: The investigations show, that a wider spacing influence positively the production of high-value oak timber and veneer not only in terms of quantity but also regarding the wood quality. The practice of silvicultural follows this result, reducing the number of plants per ha significantly from earlier 20 000 to 30 000 to appr. 5000 today.

Similar investigations are underway for spruce (Picea abies) Douglas Fir (Pseudotsuga menziesii) Poplar (Populus species) and Ash (Fraxinus excelsior).

RESEARCH DIRECTIONS FOR RECONSTITUTED WOOD PRODUCTS IN THE 90'S

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INTRODUCTION

FDC: 862: 824.8: 842

During October 1989, a two-day symposium was held in Vancouver, Canada to consider future directions for harvesting and wood products research. This event was sponsored by the Canfor Corporation in cooperation with the Faculties of Forestry and Applied Science at the University of British Columbia. The conference objective was to identify opportunities and to set research priorities for industrial and economic benefits in the areas of harvesting, structural engineering, reconstituted and treated wood products, and environmental engineering, while also indicating how university research could contribute in unique and innovative ways to achieve these opportunities.

The symposium brought together international experts from industry, universities and other research organizations with participants from management, research and development disciplines. The program was structured so that presentations of research currently taking place in each of the four subject areas were given in the first session. The second session involved formation of workshop groups in each of the specific topic areas. These groups attempted to identify limiting economic, industrial and technical progress in each area and recommended future research directions. This paper reports on the directions identified in the area of reconstituted and treated products. About ten years ago the NATO conference on Adhesion in Cellulosic and Wood Based Composites (1) also focused on identifying and establishing priorities for research in reconstituted wood products. The economic and political climate at that time emphasized concerns for resource shortages and the high cost of energy. These issues were reflected to some extent in the recommendations that evolved from this NATO conference (Table 1).

TABLE 1

Recommended Priorities from 1980 NATO Conference

- greater research effort to understand visco-elastic properties of wood based composites.
- improve information on moisture distribution patterns in composites under steady and non-steady state conditions.
- development of durability and reliability data relevant to end use in wood composites.
- improved and more cost efficient wood composite bonding through:
  - better understanding of adhesion and surface properties,
  - reduction in adhesive content requirements,
  - development of new adhesives from non-petroleum based, renewable resources.
- increased utilization of a wider range of ligno-cellulosic fibers.
- improvements in manufacturing and application techniques to save energy.

Almost a decade later, the Canfor symposium found that worries about energy costs were replaced by environmental concerns. These environmental issues impacted on all areas of the symposium, ranging from harvesting of timber to processing of pulp. It became clear that the linkage of this environmental focus with the concept of sustainable land use was leading to reduced timber availability and increased wood costs in the near future. Greater effort would need to be devoted to the utilization of lower quality wood species and wood wastes currently diverted to landfills. Environmental factors would also play an important role in changing the present and determining the preferred future manufacturing processes and uses of reconstituted wood products.

The workshop on reconstituted and treated products generated research priorities which could be categorized into three broad areas:

1. Environmental constraints

Close attention will need to be given to any material, process or product which is considered to be environmentally incompatible. Consequently, suppliers, employers, workers, and users must be educated to these situations and ultimately will demand information on the impact of chemicals and processes on the environment. This will necessitate development of new test methods and standards. Future reconstituted and treated wood product facilities will be required to operate in a closed loop system with all wastes recycled and utilized within the process. As a result, proper choice of adhesives and preservatives will become more crucial with an incentive to use only the minimum amount of treatment chemicals to maintain a satisfactory performance during the products lifetime. This concept of closed-loop-environmental-compatibility will likely extend through the total usable lifetime of the product, with the manufacturer having to insure all chemicals and processing going into the final product will not cause problems through leaching or toxicity during the lifetime of the material. In fact, products may have to be fully recyclable at the end of their lifetime.

Sawmill wastes such as bark, sawdust and shavings, while a serious problem at the present time will, in the view of the workshop members, be solved by further utilization of clean wastes in particleboard and MDF production or as an energy source.

2. Adhesives and adhesion

The presence of good adhesion is crucial to the formation of reconstituted wood products of structural integrity and long term performance capabilities. The majority of adhesives used in bonding wood are formaldehyde based, such as urea-formaldehyde and phenol-formaldehyde. Since formaldehyde is presently under increasing scrutiny and regulation because of toxicity concerns, greater attention will need to be directed towards lower formaldehyde emitting resins or resins containing no formaldehyde. Isocyanates have more recently been used to bond wood composites but these systems are also recognized as causing potentially toxic or allergic responses, especially during product manufacturing stage. Future wood adhesive developments will need to emphasize technically suitable chemicals which have limited or no effect in terms of toxicity and pollution of the environment. Indeed it may be appropriate to develop a combined adhesive and preservative system which could mutually interact to help satisfy toxicity and environmental concerns.

In terms of fundamental research in adhesives and adhesion the need was recognized for a more intensified effort to better understand basic adhesive chemistry especially when related to the mechanism of wood-adhesive interaction and cure to form strong, durable bonds. This effort should include natural, synthetic and inorganic systems. Improved methodology is also required to better measure and predict performance of adhesives in reconstituted wood products. Only by developing greater knowledge in these areas can significant advancements in both manufacturing techniques and application of wood composites be expected. Increased use of adhesives in fastener and connector technology is one example of how adhesive technology could benefit reconstituted board products by providing opportunities for improved system performance. Advancement in this area will increase wood's competitiveness with other construction materials.

3. Product properties

A wide array of reconstituted wood products are feasible depending on the size and shape of wood elements chosen. Improving performance and reliability of wood composites in order to have comparable properties to solid wood and non-wood products will require an enhanced understanding of the mechanism of board formation and the relationship of manufacturing processes to ultimate product performance.

One of the most important factors adversely affecting reconstituted wood products is moisture. The workshop group recognized that moisture content effects continue to play a crucial role in influencing the dimensional stability, strength and rheological properties of wood composites. Of particular importance to wood composites are:

- thickness swelling on edges and along panel surfaces.
- permanent loss of strength during successive moisture cycling.
- increase in creep behaviour with moisture content variation.

Consequently, strong recommendations were advanced that further study is needed to gain knowledge to allow improved prediction and control of wood/moisture content relationships in reconstituted products.

Part of the dimensional stability problem could be resolved if the compression stresses in these products were reduced. While steam pressing, high temperature heating or impregnation with polymer are feasible approaches, reducing composite density is an alternate methodology for achieving product stability. This option has the added potential for significant improvements in productivity and competitive advantage provided strength properties can be maintained. It was recommended that further study be devoted to effects of particle geometry, mat formation and pressing technology on the manufacture of improved reconstituted products. In this regard, computer processing innovations may play an important role in optimising composite manufacturing properties.

SETTING THE FUTURE PATH

In North America the transformation to second and third growth forests with its projected reduction in size and quality of wood will require wood product manufacturers to make more judicious use of this resource. As a result greater emphasis will be placed on reconstituted wood products as already is the case in many wood-scarce-regions of the world. This symposium has identified environmental factors as playing a key role in future wood composite developments, just as the theme of energy was a major concern in the previous NATO symposium. There were also research priorities commonly identified in both of these symposiums and not surprisingly these issues focus on basic wood properties such as moisture content effects and improved understanding of adhesion mechanisms in wood bonding.

This symposium also demonstrated that a combination of industrial manufacturing and research organizations could interact over a short period of time to develop some common research directions of mutual benefit. It remains to be seen whether progress can be made in these identified research priorities. Certainly this gathering has emphasized the need for a mutual assessment of directions at least every decade with the hope that a backward glance to the previous meeting brings with it some positive signs that new and useful knowledge has been developed.

STRUCTURAL PLYWOOD FROM MALAYSIAN HARDWOODS

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SUMMARY

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Twenty-two Malaysian tropical hardwood species have been categorized into two major structural groups called the Structural I and Structural II based upon specific gravity. Structural II is further divided into Strutural IIA and IIB. Species having the lowest Modulus of Elasticity in each group or subgroup are chosen and tested for their mechanical properties. Strength values of each chosen species conservatively represent the strength values of each particular group or subgroup. Preliminary tests on Keruing (Dipterocarpus spp.)and Mersawa (Anisoptera spp.) show that plywoods produced from Malaysian hardwoods are comparable in strength to those plywoods from the United States,Canada and the Scandinavian countries.

This paper is a part of a large scale research to assist in the drawing up of the Malaysian Standard for Structural Plywood.

Keyword: Structural Plywood, Tropical Hardwoods

INTRODUCTION

The timber industry in Malaysia, in general, is already aware of the concept of value added through processing rather than raw log exports. Plywood manufacture in the country is already considered a matured industry whereby the mills are capable of producing high grade panels and veneer sheets with the aid of versatile machineries and skilled workers. Technological advancements in the Far East have helped the country to be at par with many of other plywood manufacturers worldwide. Relatively low labor wages and naturally abundance of raw logs through sustained forest management further put Malaysian plywoods in the competitive edge of the market. The naturally little occurrence of defects in many of the Malaysian species veneers enhance the beauty and strength which make the plywood panels suitable to be used in decorative, structural, utility or any combination of applications.

Generally the Malaysian tropical timbers are divided into four categories: Heavy hardwood, Medium Hardwood, Light Hardwood and Softwood. There are about 57 species from the hardwood categories that are suitable for plywood manufacture, and out of these, 36 species are considered suitable for structural plywood (Wong 1985). Despite the capability of producing high quality structural plywood, many of the mills are still producing and exporting their products only as red-faced plywood or white-faced plywood. In this practice, the species and quality of the core veneer are generally not specified, and this results in plywoods of variable quality and strength properties (Wong, 1985). Therefore most Malaysian plywoods are being considered as normal utility plywood only.

The plywood industry in Malaysia are also geared towards producing plywoods according to the specifications drawn up by the purchasing countries. Therefore it is common for any particular mill to produce plywoods in just about any standard at any time. This does not mean that the products are inferior, but inconsistency in dimensions, species components,tolerance and performance among the mills' products are obvious.

Realizing this fact, many of the mills feel the need to upgrade the commercial value of their products by the support of reliable and consistent strength data which can only be achieved by following a certain specification on the production. Through their association i.e. The Malaysian Plywood Manufacturers Association (MPMA) and The Forest Research Institute of Malaysia (FRIM) they are interested to establish guidelines to develop a form of specification to standardize the plywood manufacture.

The Malaysian Standard (M.S) for Structural Plywood is in the process of being drawn up to guide the mills in producing plywoods that will be acceptable by most, if not all, purchasing countries. Being a developing country, Malaysia has the advantage of not repeating the process of establishing the best methcd of research as what were done by the developed countries. The British Standard B.S 6566 in grading of veneer is readily adopted to be a part of the M.S for structural plywood. The B.S specification is in many ways more stringent when compared to the American Plywood Association's (APA) Product Standard (PS), and being of mostly high quality, the Malaysian veneers easily comply or exceed the B.S.

To produce a practical and accurate standard, one needs to consider the individual mill capability, production technique change and specific species availability. On the other hand, a large number of strength tests needs to be done to give accurate values that can be confidently accepted by the users.

The steps in the development of the Malaysian Standard for Structural Plywood are as follows:

(1) Standardization of veneer grading that the mills will readily follow.

(2) Categorization of plywood species into structural groups.

(3) Preliminary testing of representative species from each structural group.

(4) Assignment of strength values for each structural group based upon statistical analysis.

(5) Recommendation of standard thicknesses, species structural groups and panel grades to the plywood industry.

(6) Confirmation tests on plywood produced using the recommended parameters.

(7) Draft of the standard to be distributed to the industry,government and professionals for comments.

(8) Publication of the standard after final corrections or amendments.

DEVELOPMENT OF THE MALAYSIAN STANDARD FOR STRUCTURAL PLYWOOD

Categorization of Species

Preliminarily, indicative tests to assess the strength of Malaysian structural plywood were planned to be performed on some selected species. But the multitude of species and species combination that could be used to produce any particular thickness of plywood led to the idea of categorizing the

Fig. 1: **CATEGORIZATION OF MALAYSIAN TIMBER SPECIES BY SPECIFIC GRAVITY AND RANKING BY MODULUS OF ELASTICITY**

STRUCTURAL I
(S.G 0.55-0.75)

	MOE N/mm^2
Kasai (Pometia spp.)	(2,200)
Simpoh (Dillenia grandiflora)	(2,080)
Balau,Red (Shorea spp.)	(1,990)
Gerutu (Parashorea spp.)	(1,920)
Kapur (Dryobalanops spp.)	(1,910)
Keruing (Dipterocarpus spp.)	(1,480)

STRUCTURAL II
(S.G 0.40-0.59)

IIA	MOE N/mm^2
Merawan (Hopea spp.)	(2,180)
Mengkulang (Heritiera spp.)	(1,990)
Mempisang (Monocarpia marginalis)	(1,880)
Meranti, White (Shorea spp.)	(1,840)
Bintangor (Calophyllum spp.)	(1,750)
Melantai (Shorea macroptera)	(1,640)
Kedondong (Canarium spp.)	(1,600)

IIB	MOE N/mm^2
Melunak (Pentace triptera)	(1,530)
Meranti, Yellow (Shorea spp.)	(1,520)
Kungkur (Pithecellobium confertum)	(1,510)
Meranti, Dark Red (Shorea spp.)	(1,470)
Nyatoh (Palaquim)	(1,420)*
Meranti, Light Red (Shorea spp.)	(1,350)*
Mersawa (Anisoptera spp.)	(1,340)
Durian (Durio oxyleyanus)	(1,250)*
Machang (Mangifera)	(970)

* Limited to species having S.G of 0.41

species into groups before the testing program was started.

Out of the thirty-six species that were recommended as suitable and moderately suitable for structural plywood, twenty-two species were chosen after considerations were made on their availability and practicality to be processed. These species were then categorized based upon their specific gravity into two major groups called the Structural I and Structural II (Fig. 1). The species in each group were then arranged from top to bottom according to their decreasing Modulus of Elasticity. Six common species were classed under Structural I and the rest in Structural II. Because of having relatively large number of species Structural II was further subdivided into two subgroups called the Structural IIA and Structural IIB.

One species from each group or subgroup was taken as the representative species to be tested. Keruing was taken to represent the Structural I group while Kedondong was taken to represent the Structural IIA group.

For Structural IIB, even though Machang was the weakest, it was thought that either Light Red Meranti or Mersawa should represent the subgroup since each contains variety of subspecies in addition to being the more common species processed in the mills.

These species ie. Keruing, Kedondong and Light Red Meranti or Mersawa were to be tested for their strength properties, and being in the weakest end of their appropriate groups, their strength would conservatively be representing the strength of the other species in the group.

TEST METHODS

For the purpose of establishing basic strength data seven mechanical testings were planned to be performed on the plywood samples. The tests were performed on small clear specimens to the methods stipulated in the American Society for Testing and Materials standards (Anon. 1988). The tests were as follows:-

Static Bending - ASTM D3043

Compression - ASTM D3501

Tension - ASTM D3500

Panel Shear - ASTM D2719

Rolling Shear - ASTM D2718

Shear Modulus - ASTM D3044

Toughness - ASTM D3499

The veneers for the panels to be tested were graded by the B.S 6566 method of veneer grading whereby veneers of Grade-E denotes the best grade with virtually no defects.

First four tests of the above were completed for the Keruing Grade-E and Mersawa Grade-E, 4.8mm 3-ply, plywoods at this stage. These tests were for both face grain parallel to span or force and face grain perpendicular to span or force where applicable.

RESULTS

The mean ultimate values of Mersawa Grade-E and Keruing Grade-E are as shown in Table 1.

Generally, Keruing plywoods which were having higher specific gravity (S.G 0.72) were stronger than Mersawa (S.G 0.56) in all of the mechanical tests.

The strength of all the plywoods, regardless of their species, were higher when tested with the face grain parallel to direction of force or span as compared to face grain perpendicular to direction of force or span.

In static bending test, the extreme fiber stress or Modulus of Rupture (MOR) of Keruing was about 30% larger than Mersawa for both directions of face grain. When strength under static bending was compared between face grain directions, the MOR for face grain parallel to span was three times higher than MOR for face grain perpendicular to the span, and this was true for both species. The plywoods was also stiffer by about 17 to 18 times when force was introduced parallel instead of perpendicular to the face grain.

Comparing species to species for compression and tension tests, Keruing had maximum stresses that were between 26 to 32% higher than Mersawa when force was acted parallel to the face grain, and about 34 to 40% higher than Mersawa for force acted perpendicular to the face grain.

Under compression test alone, the maximum compressive stress in the direction parallel to face grain was higher by about 87 to 99% than the other direction for both species. While for tension test, the tensile strength in direction of the face grain was about 42 to 50% higher than tensile strength perpendicular to the face grain.

Table 1: Mean ultimate strength of 4.8mm 3-ply plywood

TEST	MERSAWA Grade-E		KERUING Grade-E	
	Direction of force to face grain or span			
	parallel	perpendicular	parallel	perpendicular
Static Bending				
MC %	11.60 (0.267)	11.23 (0.31)	11.73 (0.22)	11.5 (0.195)
SG	0.562 (0.0203)	0.557 (0.0151)	0.734 (0.0185)	0.716 (0.0233)
MOR N/mm^2	66.81 (6.68)	15.71 (2.59)	89.6 (6.78)	20.86 (3.66)
MOE N/mm^2	11,484.75 (1259.8)	639.16 (99.14)	15,083.5 (1034.8)	762.1 (144.2)
Compression				
MC %	11.13 (0.243)	11.31 (0.552)	11.56 (0.187)	11.55 (0.290)
SG	0.564 (0.0202)	0.552 (0.0176)	0.729 (0.018)	0.70 (0.020)
Max. Comp. Stress N/mm^2	25.35 (2.530)	12.73 (1.293)	33.51 (2.106)	17.93 (2.504)
MOE N/mm^2	3346.7 (710.5)	2071.41 (445.65)	5720.5 (965.2)	2499.8 (995.39)
Tension				
MC %	13.40 (0.163)	13.45 (0.1996)	13.17 (0.154)	13.23 (0.183)
SG	0.56 (0.017)	0.548 (0.0187)	0.72 (0.017)	0.701 (0.023)
Max. Tensile Stress N/mm^2	51.87 (8.26)	34.61 (6.34)	65.59 (9.59)	46.27 (9.08)
MOE	6675.4 (1130.2)	3917.5 (465.2)	9462.5 (2186.9)	5954 (1144.8)
Panel Shear				
MC %	9.75 (0.968)		10.32 (0.648)	
SG	0.561 (0.017)		0.720 (0.0186)	
Max. Shear Stress	7.595 (1.359)		7.988 (1.449)	

Note: Standard Deviation in parentheses

Only small difference was observed between Keruing and Mersawa when they were tested for their shear through the thickness strength. Panel shear strength for Keruing was about 7.988 N/mm^2 while Mersawa was 7.595 N/mm^2.

The deviation in strength values when force was acted perpendicular to face grain or span was usually high and could vary by as much as 20% around the mean value, and this was particularly true for the tensile strength test. Defects that might exist in the core could have affected the strength and caused the variation.

The variations in moisture content and specific gravity of the samples tested for every test were small except for panel shear test. Due to their irregular shape and size, the samples for panel shear test had to be conditioned in a bigger conditioning room where the relative humidity was difficult to control. The large variation in the R.H had caused large variation also to the moisture content of the samples. Nevertheless, the variation was only in the region of 6 to 10%.

DETERMINATION OF BASIC STRESSES

For the purpose of comparison between Malaysian hardwood plywood with other plywoods from different countries, the mean ultimate values in Table 1 were reduced to their basic stresses and moduli values. Due to lack of other research on Malaysian plywoods, the method of determining basic stresses for solid wood as stipulated in Malaysian Forest Service, Trade Leaflet No. 37 was adopted (Engku 1980).

Identical to solid wood, the definition for basic stress of plywood is "the stress which can safely be permanently sustained by plywood containing no strength reducing characteristics". The modification factors used were for the variability of strength and factor of safety.

To account for the variability of strength, the following probabilities and formulae were used:

Property	Probability	Formula
Bending	1 in 100	$\bar{x}$ - 2.33 S.D
Compression	1 in 100	$\bar{x}$ - 2.33 S.D
Panel shear	1 in 100	$\bar{x}$ - 2.33 S.D
Tension	1 in 100	$\bar{x}$ - 2.33 S.D

Factors of safety to account for items such as accidental overloading, errors in design assumptions, and mistakes in analysis and fabrication were as follows:

Property	Factor of Safety
Bending	2.5
Compression	1.5
Panel shear	2.5
Tension	2.5

The basic stresses for Mersawa Grade-E and Keruing Grade-E plywoods are as in Table 2.

Table 2: Basic Stresses for 4.8 mm 3-ply Malaysian Plywood

TEST	Mersawa Grade-E		Keruing Grade-E	
	Direction of force to face grain or span			
	parallel	perpendicular	parallel	perpendicular
Static Bending				
MOR (N/mm^2)	20.50	3.87	29.52	4.93
MOE* (N/mm^2)	11,484.75	639.16	15,083.50	762.10
Compression				
Max. Compressive Stress (N/mm^2)	12.97	6.48	19.07	8.06
Tension				
Max. Tensile Stress (N/mm^2)	13.05	7.94	17.30	10.05
Panel Shear				
Max. Shear Stress (N/mm^2)	1.77		1.84	

Note:**MOE is taken as the mathematical mean**

Table 3: Basic stress for plywoods from various countries

TEST	U.S PSI-74** (C-C STRESS GRADE) (8 mm 3 ply)		FINNISH BIRCH** (SANDED) (6.5 mm 5 ply)		CANADIAN DOUGLAS FIR** (Select and sheating grades) (7.5 mm 3 ply)	
	Direction of force to face grain or span					
	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
Static Bending						
MOR (N/mm^2)	11.4	3.50	19.0	9.79	11.6	2.78
MOE (N/mm^2)	10,750	900	10.750	4,000	12,350	850
Compression						
Max. Compressive Stress (N/mm^2)	7.63	3.97	8.95	5.63	7.99	3.22
Tension						
Max. Tensile Stress (N/mm^2)	5.22	3.20	14.9	7.79	5.13	2.14
Panel Shear						
Max. Shear Stress (N/mm^2)	1.73		3.51		1.82	

** extracted from BS 5268: Part 2: 1984

Note: Due to the different plywood thicknesses and grades, testing procedures, factors of safety and analysis theories (either full area or parallel ply theorem) amongst the countries, the values in Table 2 and 3 are only for strength and moduli indication of the plywoods and cannot be directly compared without proper balancing and judgement.

Table 3 shows the basic stresses for plywoods from other countries. Direct comparison between stress and modulus values from these countries cannot be done directly due to the different plywood thicknesses and grades, testing procedures, factors of safety and analysis theories. Australia and the U.S.A use the `parallel ply theorem' for their analyses while U.K uses the `full area' method. For the purpose of this paper the `full area' method was adopted because it was quite impossible to get final thicknesses of the veneer plies after the cold pressing and hot pressing of the panel. However, these values are the indication of strength for Malaysian plywood at least for the 4.8 mm 3-ply construction. Strength data for other thicknesses and construction will be made by the use of the formulae already developed and will be confirmed by extra testings in the next level of this study.

Undoubtedly the modification factors used in deriving the basic stresses are necessarily conservative at this primary stage. A more refined basic stresses for Malaysian plywoods could be produced in the near future when modifications factors are derived by further researches on Malaysian plywoods.

CONCLUSION

Plywoods produced by Malaysian mills are of high quality but suffers downpricing due to lack of supporting data on strength and moduli. The Malaysian Standard for Structural Plywood is being drawn up to guide the local industry, and perhaps any plywood industry from the tropical region, into producing more consistent products that would gain confidence from the purchasing country.

Preliminary tests have shown that the Malaysian species currently used for plywood manufacture do have comparable or of even better strength than the plywoods made by other countries where the production of plywood is already standardized. The basic stresses presented here are conservative due to the still primary steps undertaken in the research on Malaysian plywoods.

The principal tests for Keruing and Mersawa have already given the indication of strength for the proposed Structural I and Structural IIB grades respectively. Even though the samples prepared for the testings were of one species panels, the manufacturers are not demanded to do same to acquire the basic strength for a particular strength group. They are free to mix species in the lay-up and the basic strength of the panel will be dictated by the weakest species. Although the weakest species would uneconomically to a certain extent be the single degrading factor to the other stronger species, the plywood panel could be confidently said to have the minimum strength for the particular strength group.

Secondary test for these plywood are ongoing and will later complement the tabulation of strength data for these structural grade plywoods. When more data are gathered it can be seen that being normally of hardwoods and naturally less occurrence of defects, the Malaysian plywoods are of superior strength compared to the softwood plywoods.

Thus, when further tests are completed, a practical and logical specification for production of Malaysian structural plywood including the basic strength data for the final product made to that specification would possibly be drawn up, and the already saleable Malaysian plywood can be accepted for structural use confidently.

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PROCESSING TOMORROW'S WOOD COMPOSITES

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ABSTRACT

The wood and wood/nonwood composites industry is a creature of the 20th Century. Most of the development has taken place since 1960. The pace of the development has been rapid and a continued rapid pace of industry development is expected into the 21st Century. The processing of tomorrow's products is expected to be enhancements of today's technologies. However, technological breakthroughs with quality control devices, processing machines, nondestructive testing, new and better adhesives, and the use of previously unused raw materials all will enhance the future of these composites.

International standardization and the development of reliability based design procedures for the use of composites in structures also will brighten the future for composites. Composite manufacture is an important way to use residues and other presently unused wood raw materials for society's ever growing needs.

INTRODUCTION

Looking into the future and forecasting new composites and new processing techniques is a formidable task. The first question, then, is what are tomorrow's composites? It is probably safe to say they will be based on today's composites. There will continue to be the evolution of processing that has taken place over the past 50 years or so. There probably will be more molded or three-dimensional products. The products, as is the case today, will be made to fit into the construction systems employed or as material for furniture, cabinets, and other such products. Innovative new ideas will come along and will be implemented, as has been the case throughout the history of forest products.

In this fast-paced world of ours, one might overlook how quickly development takes place. Today, most of the items we call composites (wood materials glued together) have been invented and brought into use in fairly recent times. Softwood plywood (modern day) manufacture started in 1905, but reached its great production rates after World War II. Cement-bonded products were first developed in 1914. It is only now, however, that these products are being manufactured in many countries at significant levels. Insulating board (softboard) also started manufacture in 1914, but it is now a declining product because of pollution problems and competition from plastics. Hardboard came along in 1924 and is still a very significant product manufactured worldwide; however, its market is being impacted by dry-process thin boards and, in the case of siding, by oriented strand board (OSB).

Particleboard did not become a significant industry until the 1950s. Extruded particleboard was manufactured worldwide starting in the late 1940s, but now there is little that is produced because of certain poor properties. Waferboard was first manufactured in Idaho in 1955. The waferboard plant ran until 1974, but the first major production going into structural applications started in Canada in the mid 1960s. Oriented strand board (OSB) has been known since the 1950s, but it did not become a major product until the 1980s. Most plants that previously produced waferboard now produce OSB because of better properties for structural applications and because less material is needed with strand orientation.

Medium density fiberboard (MDF) started in the United States in the 1960s. Now this premium furniture material is manufactured worldwide. The 1980s were a time of explosive growth.

Molded products go back into the 1940s and 1950s. Massive growth in this part of the industry has not taken place; however, the blending of wood and plastic fibers to make superior molded parts for automobiles has lead to a very significant market.

Laminated veneer lumber (LVL) was developed in the 1960s, was manufactured in volume starting in the 1970s, and is now a high-volume premium product. Now, oriented strand lumber (OSL) will soon be manufactured. COM-PLY® lumber (veneer edges and flakeboard cores) is already being manufactured. Heavy timber material, Parallam® or parallel strand lumber (PSL), has been manufactured for several years in a small pilot plant. Two large plants are now, or will soon be, in production.

New versions of cement-bonded materials and the quite new gypsum-bonded flakeboards and fiberboards are being manufactured also. The gypsum-bonded fiberboard is a promising competitor to conventional gypsum board or sheet rock in the 1990s.

This long discourse shows that the composites of today are many, but are of relatively recent origin. The forest products industry has made enormous advances in the field of composites during the latter half of the 1900s.

Viewing these developments from 1950 on, one is awed about the science, technology, engineering, production, and managing that has lead to the wide array of new composites and enhanced composites. The forest products industry has been a leader in industry in general. It has provided, also, valuable building and other useful materials from a renewable resource.

In this presentation, the plan is to look ahead to perhaps 2010 and discuss the wood raw materials, materials that can be used other than wood, future products or variations of present products, and new processing needs or techniques.

WOOD RAW MATERIALS

The various segments of the composite products industry have developed by utilizing the easy-to-use wood raw materials. Lower density species (firs, pines, poplars) have been the dominant raw materials because of the ease in cutting or refining veneers/particles/flakes/fibers and, because available resins worked well in gluing these species. Utilizing these species is natural for the above mentioned reasons. Countries having to rely on higher-density species and a great variety or mixture of species have had much greater problems in producing composites. Cutting is much more difficult, adhesive bonding may be a problem because of the varying chemistry of the species, and the resultant products probably will have a greater weight. Tropical forests, for example, present such problems and plywood, to date, has been the only real composite success story in these areas.

However, as the world's population continues to grow (4 billion to 5 billion people in the last 10 years) and forested land continues to decrease, the need for successfully utilizing the hard-to-use species becomes a critical goal. As it is, the pine and fir forests are being harvested at earlier ages than before which means an increasing amount of less desirable juvenile wood going into a product. Fortunately, it appears that juvenile wood negatives can be overcome in most composite materials.

For the most part, a resource now used only for steam and energy generation is hog or boiler fuel. This material, primarily from sawmills, is a mixture of all residues not used for other products. Burning this fuel for steam and energy is practiced in many places. However, even in industrialized countries, a surplus is developing of such raw material. Separation techniques need to be developed that will recover the various constituents of the hog fuel separately. In the past, boards of bark have been shown to have unique properties. Bark board development was terminated in the United States when the rush to generate in-plant steam and energy from hog fuel began in the 1970s. Perhaps bark in particular should be reconsidered for products of the future.

Another resource available and one that has been used to some extent for many years, is wood that has been recovered from municipal waste. This has been used for particleboard in both the Federal Republic of Germany and also in South Africa (Pagel 1979; Fischer 1981). Research has been conducted on dead wood from the forest (up to five years old) showing that such wood is a valuable resource. Such material is being used successfully for particleboard and hardboard.

MATERIALS OTHER THAN WOOD

Other fibrous materials (nonwood) have been and are being used for particleboard, MDF, and hardboard furnish. Bagasse has been the most widely used; but straw, jute, cottonstalks, and kenaf are among the other materials that can be used successfully for board. In the future, more of these materials will have to be used. At present, there is a plan to produce paper in Texas, USA, from kenaf only. This kenaf will be grown just for the pulp and paper plant, but it shows the potential for board plants where wood is scarce and crops such as kenaf can be grown.

Other key materials in the area of composites are the adhesives. The basic adhesive systems of urea-formaldehyde, melamine, melamine-urea-formaldehyde, phenolic, and isocyanate will remain the dominant systems in the foreseeable future. There are constant modifications and improvements in these systems. Significant efforts have been made in developing nonpetrochemical systems, but few systems except for the wattle tannin system, have been successful. However, significant work is underway, particularly with urea-formaldehydes. Some researchers believe with modern measuring and analyzing techniques, methods can be devised to make urea-formaldehydes water resistant.

Most wood products are involved with glue in some way. With both an enormous need and also a potential for sales, it should be reasonable to expect further breakthroughs in developing adhesive systems, or for that matter, completely new systems.

The great problem with wood is its "ability" to shrink and swell with the loss or absorption of moisture. Moving into the future, chemical modifiers or process treatments should be developed to inhibit the shrinking/swelling of composites. Chemical modifying with acetylation and steam treatments have already been shown to be methods for improving dimensional stabilization (Rowell and Youngquist 1988, Hsu 1987 and 1989).

Fire problems have always been of concern with wood. Fire retardant composites have not shared a large part of the wood products' market. Much more work needs to be done in this area, as it opens up tremendous opportunities for fire retardant composites which can compete with nonwood building materials.

Likewise, better and less costly treatments for producing decay resistant composites are needed. It is well known that great changes have been taking place in the treating industry as certain long-used chemicals have been banned or have had their use limited. Again, modern science and technology should be of great assistance in improving this market segment for composites.

THE FUTURE PRODUCTS

Products in the future will consist of "more-of-the-same" (as is now being produced). These are valuable materials serving a multitude of needs. These products, however, are mostly basic parts. Some place, other than the wood products plant, usually makes the overlayed products, finishes, cuts-to-size, and completes the final product. Already well underway, more primary production plants will get into secondary (value added) production. Overlaying, finishing, cutting-to-size, edge banding, mitre folding, and even final product manufacture (such as furniture) will become more common.

Much larger structural panels will be used in ever increasing quantities, particularly in nonresidential large structures. Since cranes are usually already on the site, the erecting of large panels is not a problem. The use of large panels is more efficient and provides better construction because of fewer joints. Such large panels also work well in factory-built houses. This has been demonstrated in actual practice for many years.

Lumber products will continue to be developed. Indeed, there is great potential for composite lumber products as the quality of the forest decreases in terms of sawlogs. The PSL 300 product of MacMillan Bloedel for use in window frame construction will soon be available. Furniture material of OSL such as Weyerhaeuser's Heartwood™ will continue to be developed. Heartwood™ is not only a composite material for structural use, but is a beautiful material when finished.

MDF can be carved and turned into beautiful products. It can also be used as a fine lumber substitute with proper finishing. MDF is already used this way and in the future there should be a tremendous increase in such applications.

There will be more products of combinations of wood and other materials. Metal- and fiberglass-faced panels have been used for many years. Plastic-covered wood parts for windows has been another long time successful product. More materials such as the wood/plastic fiber mix for molded automobile parts, will combine wood and other materials intimately. The blends of materials take advantage of the best properties of all of the different materials.

Molded products will start to expand their share of the market place. Technology, developed painfully over many years, is available for producing such products. The molded fiberboard door skin has been an enormously successful product line. Molded window, door, and furniture parts have been made for many years as has the successful molded pallet. Molded I-beams and trusses have already been developed in the laboratory. The U. S. Forest Products Laboratory is developing Spaceboard, a structural molded product of the type of fiber used for paper.

Orientation of strands has lead to OSB and the varieties of oriented strand lumber. Orientation of smaller particles fiber and admixtures of particles and fiber presents possibilities of producing superior products using these smaller particles (Talbot 1974, Peters 1983, Koenigshof 1983, and Fyie et al. 1985).

The production of more components ready-to-use appears to be a trend. Competitors such as the General Electric Plastic House are exploring wood markets, as they have for years. Prefabricated plastic houses have been produced in Japan for several years. Such progress will call for more developments in automated- and robot-controlled manufacture. Much of this type of computer-controlled manufacture has been developed for other industries. It would seem that some of these developments will be adapted to the wood industry in the very near future.

New products will be developed that are not even imagined today. Who would have thought, twenty years ago, about the conductive particleboard developed by Boise Cascade Corporation for use in computer rooms (Lambuth 1989)?

Manufacture and trade of products throughout the world is increasing constantly and changing. To facilitate trade, as expressed by many people over the years, the development of internationally recognized standards for all of the composite products is needed. It is understood that such standards developments is very difficult to achieve because of company, country, and regional self interests. Work has gone on in this area for many years through the efforts of the International Standards Organization. Now their work is contributing to the development of common standards for much of Europe. Perhaps the development of these common standards will hasten the development of international standards as Europe is both a very large population and also a large product-consuming area.

Another great need is the development of engineering design values for all of the wood and wood/nonwood composites. The introduction of reliability-based design into the forest products industry should help in developing the engineering design value for composites and, thereby, help expand the market for composites. Some composites such as structural panels and LVL already are in a position to take advantage of the new reliability-based design procedures for wood construction.

PROCESSING

Virtually all of the processing techniques now used for composites are creatures of the latter half of the 20th Century. It is possible to take the view that similar developments could occur in the next 50 years. While this may be an optimistic view, it is one the author feels will be the case.

Obviously, more computer control will be used on all production lines. It will not be long before the production lines will be interlocked with computers controlling the entire process. Significant difficulties have been encountered in getting the computer systems that are already developed to work well in plants. The plant difficulties have come from the computers and software, as would be expected in any development, and because of the many variables in the process attributed to the wood itself: adhesives, cutting, milling, drying, adhesive application, laying up or forming, prepressing, and pressing. All-in-all, however, the computerization of the various processes has advanced tremendously.

There will be continued savings in energy. Savings in energy is a significant factor in processing profitability (Neill 1985).

Quality measurements will be needed at every step of the process and the information that is gained fed back into the control system(s). Many devices for automatic quality measurements such as for moisture, thickness, and weight are already in place.

Nondestructive testing of raw material, product in process, and final product, will be even more necessary to help with quality control within the plant and to insure quality of the final product in use. The customer will grow to expect nothing but the quality promised (Maloney and Pellerin 1987).

Nondestructive testing has already proven its worth with machine-graded lumber (MSR) and LVL. Indeed the LVL industry could not have evolved without nondestructive testing. The industry was developed to produce mainly high strength LVL. By using nondestructive testing, high-strength veneers are selected and placed in the outer plys of the LVL. This results in consistently high-quality LVL. Without nondestructive testing, LVL would be assigned lower-strength values simply because of the random layup of veneers of varying strength. LVL would be more like a standard grade of lumber rather than the high-value product it is.

Softwood plywood manufacture, on the surface, does not appear to be much changed from 1905. However, just in the last 15 years there has been tremendous changes. Logs not previously used because of their small size are now efficiently and routinely peeled at high speed. Lathes, clippers, moisture detectors, dryers, layup sections, adhesive formulations, prepressing, pressing, and conditioning after pressing have all been redesigned or invented in the recent past. Now the Panel 100 process system (Mason 1989) for making plywood in 8 ft (2.44 m) squares has been developed. It is easy to see how such a process could be expanded to produce 8 by 24 ft (2.44 by 7.32 m) panels or to produce a panel by continuous pressing. The system produces plywood at a much lower cost.

Likewise, hardwood plywood has seen great changes in technology from the lathe through drying, composing, and pressing. Lengthwise slicing and vertical presses are other relatively new developments (Pollmann 1987).

A number of improvements can be forseen for the various composite production lines. These will be divided into veneer products and particle/strand/fiber products.

Veneer Products

Before even introducing the logs into a veneer line, the logs will be evaluated for quality. Lower-quality logs can then be diverted to other product lines or be converted into chips before the costly process of veneer production begins. Ways to nondestructively evaluate logs for quality are ready for use.

The development of better lathes has already been mentioned. Further improvements should be expected in providing better veneer surface smoothness, great flexibility of veneer (say by the incising method already developed), and a reduction of veneer length (thus, saving material).

Better drying will be accomplished by accurately measuring green veneer for moisture and directing the veneer to the appropriate drying system. The drying system might range from today's conventional dryer to high frequency drying.

Veneer will be separated by strength and placed in the appropriate location within the final product to either take advantage of a particular property or to minimize the detrimental effect of a poor property. This is already being done with LVL, as mentioned previously.

Glue application and more efficient use of glue have seen major production advances in recent years. Perhaps the limit has been reached with present day adhesives. However, new composing of veneers and continuous pressing can reduce waste dramatically . Currently, in 4 by 8 ft (1.22 by 2.44) softwood plywood production as much as 16% of the panel (surface measure) can be trimmed off and lost as waste. By going to the production of larger panels such as the Panel 100 process in a larger press or in a continuous press dramatically reduces the waste. Considering an 8 by 24 ft (2.44 by 7.32 m) panel cut into 4 by 8 ft (1.22 by 2.44 m) panels, the waste is reduced to about 7% (surface measure).

The development of glues and processes to glue higher moisture content veneer than in the past has lead to production economies in softwood plywood manufacture. Gluing higher moisture content veneer results in a product also with a higher moisture content (Detlefsen 1987). This is a valuable development as the product leaving the plant is approximately at the equilibrium moisture content found in actual use. Little dimensional change takes place in such plywood after it arrives at the building site.

New developments expected in producing LVL are reductions in press time through steam pressing or high frequency pressing. Reducing press time from the present 18 to 20 minutes for the 1 1/2 in. (38 mm) thick LVL will increase productivity greatly.

Particle/Fiber/Strand Products

Wet Process

Most of the emphasis in recent times has been on dry-process systems. Wet-process systems have been perceived as having water pollution problems. Great strides forward have been taken in solving water pollution problems and plants operating today are meeting the environmental standards in their areas.

Further improvements in wet processing are taking place, keeping wet processing as a viable method for board production. There is better control of the whole system, better chip washing, fewer losses in wet mat forming, and newer methods to take care of polluted water. One such method is to evaporate the polluted water to concentrate the impurities to about 30 - 40%, and then to burn this concentrate in the boiler. The impurities are disposed of and some energy is generated.

Dry Process

It has been a long-time desire for producers to identify the species found in residues received at the plant. This measurement of quality would be of immense value to those companies struggling with a variety of species including ones that cause production problems such as with resin bonding. There is a difficult challenge to identify species in mixes such as shavings, but such a development could be quite beneficial.

Tremendous advances have taken place in flaking and fiberizing. Now it is possible to cut strands up to approximately 18 in. (46 mm) in length. Better ways to remove bark, particularly from small logs, is a great need. This would result in better quality particles, particularly of the flake and strand type.

Great improvements in drying should be forthcoming. Methods for grouping the furnish to be dried into moisture level classifications will enable the use of separate drying procedures for different moisture levels. This will provide better quality furnish. Also, it will enable better control of dryer effluents which are coming under greater environmental restrictions. Real and perceived air pollution is a problem that needs to be handled both technically and politically.

Classifying the furnish will become more sophisticated and precise. For those manufacturers needing products with perfect surfaces, it will be imperative to develop classification systems which will insure the economical removal of undesirable particles.

Laboratory research has established that lesser amounts of resin can be used in board production than what is used in industry. The difference between optimum laboratory and industrial conditions has been narrowed significantly in recent years. The immediate blending needs are to improve methods for long strand [up to 18 in. (46 mm)] blending and to eliminate blowline blending in MDF production. Blowline blending was introduced to eliminate resin spots on the MDF board surfaces and has been successful. Now, however, with the demand for even better board surfaces, subsequent "secondary" treatment of the furnish is needed to eliminate very fine balls of fiber and resin. A system is needed to efficiently apply resin without any balling of the fiber.

Mat forming has improved markedly over the years. Better controls and computer operation are producing more uniform mats. Precise classification of the furnish may make mat forming even better. The greatest difficulty in mat forming is found with the strand type products. It is difficult to lay up a mat of uniform density because of the large size of the strands. Improvements such as a slight vibration of the mat as it is being formed may make it possible to produce mats and boards with more uniformity in density and, hence, in properties.

In the future, more continuous pressing appears evident. Continuous press improvements are making the presses more economical to operate. Also, the trim losses are reduced, as described under the section on Veneer Products.

Single-opening and, particularly, multi-opening presses will remain solid mainstays of the industry. Some companies will prefer these time-tested machines for certain product lines. Also, in developing countries, these presses may be simpler to operate, depending on the technical skills available.

Of great interest is the recent development of steam pressing. Several plants using this technique are already operating (Siempelkamp 1989). It is a particularly good process when producing thicker boards. Advances in steam pressing should be expected as new research is conducted and production experience is gained.

High-frequency pressing has been used successfully both in the past and also currently. It is also a good process for producing thicker composite products. Recent developments are making the use of high-frequency pressing a more attractive process. In the past, problems with the electrical circuitry have caused plants to stay away from high-frequency pressing. Now with modern solid state electronics, high frequency is being used very successfully.

There has been a revolution in composite pressing during the last 50 years. Literally nothing was known about pressing as it is now practiced in 1940. The next 50 years should see similar changes for the better.

The ultimate goal of those involved in the particle/fiber/strand field is to produce a board economically with excellent properties and little densification. The compression of these boards leads to the swelling and expansion problems which may occur. A significant step in economic production with little densification has been the development of the MDF Liteboard™ by Nelson Pine Industries of New Zealand. This excellent appearing board has a specific gravity of 0.60, much lower than traditional MDF.

SUMMARY

Figure 1 illustrates the many facets involved with producing the products of tomorrow. The evolutionary development of both products and processing will continue. There will be a continued movement from making parts to producing components and final goods. There will be better use of material in the plant, better quality control, less waste, and products leaving the plant will have assured quality and properties. Materials not used previously, both wood and nonwood, will be utilized for the products of the future through necessity where materials are in short supply and, additionally, to take advantage of nonwood materials' particular properties.

Enormous amounts of research and development are yet to be done. Based on the recent past, there is no reason to believe that this research and development will not be done. Indeed, the author is confident that new research and development will result in an industry providing more and better materials than in any other time in the past.

Perhaps the greatest challenge of all is to develop wood composites that replace materials made of nonrenewable resources. In the past, for the most part, wood composites have replaced other wood materials. Now is the time to assist society in conserving irreplaceable nonrenewable resources by developing wood composites for new applications. It is up to the industry in the new future to develop the options for future development of the wood and wood/nonwood composites.

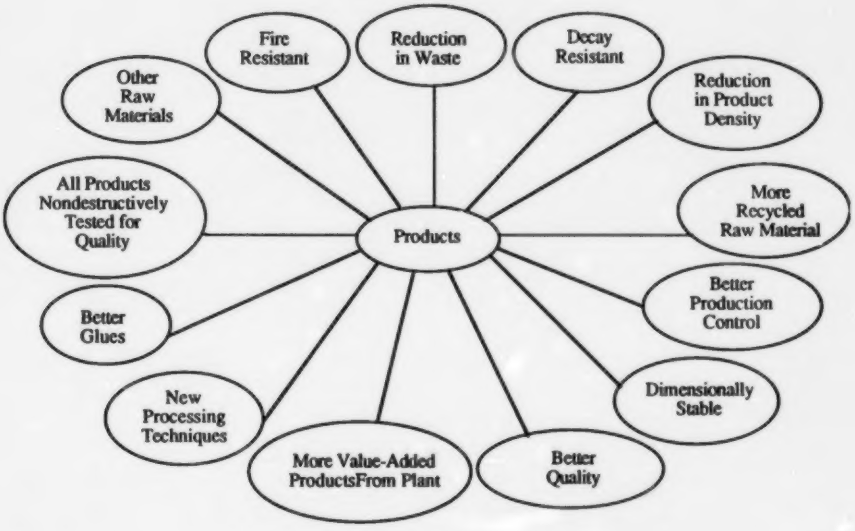
Fire Resistant
Reduction in Waste
Decay Resistant
Other Raw Materials
Reduction in Product Density
All Products Nondestructively Tested for Quality
Products
More Recycled Raw Material
Better Production Control
Better Glues
Dimensionally Stable
New Processing Techniques
More Value-Added ProductsFrom Plant
Better Quality

Figure 1. *Products of Tomorrow*

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COMPOSITES AS A WAY TO ADD VALUE TO THE TIMBER RESOURCE

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SUMMARY

Many local, regional, and national economies are dependent on the forest resource for a substantial amount of income and employment. Too often, however, the timber resource is harvested and exported without capturing the economic benefits obtainable from further processing, which adds value to the product. This paper presents a method of ranking the relative contribution of major primary timber processing operations to the economy. The method uses existing indicators of economic activity within each of the primary processing industries. These indicators include the total value of products shipped, the value added to the resource through the manufacturing process, and the ratio of value-added to value of shipments. This ratio of value-added to value of shipments provides a means of comparing the relative increase in the value of the timber resource across all primary processing operations. I applied this method of ranking values of shipments and value-added to primary processing industries in the United States. My results indicate that the further processing of timber into composite wood panel products will add more value to the resource, and hence to the economy, than the manufacture of primary wood products. Because the magnitude of the economic activity indicators used here are specific to conditions in the U.S. economy, this analysis must be performed for each country or producing region of interest.

Keywords: Wood composites, value-added, industry shipments, timber resource

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INTRODUCTION

The wise use of the resources of the world's forests can provide both direct and indirect economic benefits to national, regional, and local economies. Activities such as the harvesting and processing of timber, leasing of water and grazing rights, and development of tourism and other outdoor recreational activities all help stimulate the economy. For example, timber harvesting, including stumpage payments made to landowners and payments for transporting roundwood to processing sites, represents both employment and income. Forest-related activities that increase economic benefits to the economy, while retaining the integrity of both the forest resource and other forest-related activities, are beneficial and should be encouraged.

This paper examines the economic benefits derived from the timber resource in the United States. Of particular interest is the contribution made by the solid-wood primary timber processing industries. This includes both the harvesting of the timber resource and its conversion into lumber, plywood, composite wood panel products, and treated wood products. Aggregate indicators of economic activity in each primary processing industry will be presented, and economic benefits will be evaluated using a value-added method developed in this analysis. Finally, recommendations are made for stimulating local, regional, and national economies through additional processing of the timber resource. Of particular interest is the role the production of composite wood panels can play in increasing economic benefits derived from the timber resource.

Data and analyses presented for timber-based manufacturing in the United States are based primarily on information collected by the United States Department of Commerce, Bureau of the Census, in its quinquennial Census of Manufactures (U.S. Department of Commerce 1985, 1989). Although specifics will vary, the concepts developed here have general applicability to other forest resources and countries.

U.S. TIMBER PROCESSING INDUSTRIES

Timber harvesting and manufacturing supports employment and income in many sectors of the economy. Roundwood provides raw material for many different manufacturing industries. For example, sawmills and paper mills process roundwood directly into lumber, newsprint, and other marketable primary wood products. Some industries purchase these products to manufacture more highly finished secondary goods, such as cabinets, furniture, pallets, paper bags, and high-grade paper products. Producers of gum and wood chemicals also rely on timber for raw materials. All the wood manufacturing industries rely on the roundwood forest resource for income and employment (U.S. Department of Agriculture 1988).

There are several ways to measure the contribution of timber harvesting, and primary and secondary forest industry manufacturing to the economy. The number of timber-based establishments, level of employment, payroll expended, value added in the manufacturing process, and value of shipments all indicate how the forest industries affect local, regional, and national economies.

Value of shipments, as defined by the Bureau of the Census, is "the received net selling values of all products shipped, both primary and secondary, as well as all miscellaneous receipts such as receipts for contract work performed by others, installation and repair receipts, sale of scrap, and sale of items bought and resold without further processing. Included are all items made by or for the establishment from materials owned by it whether sold, transferred to other plants of the same company, or shipped on consignment" (U.S. Department of Commerce 1989). Value-added "is derived by subtracting the cost of materials, supplies, containers, fuel, purchased electricity, and contract work from the value of shipments plus receipts or services rendered. The value is then adjusted by the addition of value added by merchandising operations plus the net change in finished goods and work-in-process inventories between the beginning and end of year" (U.S. Department of Commerce 1989). Thus, value-added is a net measure of an industry's contribution to the economy because the value of materials received from other firms and used in the manufacturing process is subtracted from the value of the products shipped.

The two-digit Standard Industrial Classification (SIC) code (Office of Management and Budget 1972) defines three major industry groups and one individual industry that primarily use or manufacture products from wood. The Bureau of the Census uses this classification system for data collection. These industries are Lumber and Wood Products (SIC 24), Furniture and Fixtures (SIC 25), Paper and Allied Products (SIC 26), and Industry 2861--Gum and Wood Chemicals. The data base of the Bureau of the Census includes the total activity of these industries, although timber is only one of the raw materials used. The data base does not include the economic importance of these forest industries as producers and consumers of goods and services provided by nontimber sectors of the economy. Nor does the data base measure the multiplier effects generated from income and employment in forest industries that spread throughout the economy.

Each two-digit major industry group consists of two or more individual four-digit industries. Individual manufacturing establishments are assigned to the industry that most closely reflects the principal product manufactured. However, many individual establishments manufacture products of more than one industry. Consequently, industry data do not fully reflect the activity required to manufacture the principal product. For example, a mill that produces pallets is assigned to Industry 2448--Wood Pallets and Skids. However, the mill may also produce a small amount of other products, such as wooden containers or cooperage. Ratios of industry specialization and coverage are reported for each industry; they define the levels at which nonprimary products are manufactured within the industry and at which primary products are manufactured outside the industry. In addition, economic data are reported in current U.S. dollars; the data reflect changes caused by industry activity and by inflation.

For this analysis, industry specialization and coverage ratios were used to convert industry economic data to data that more fully reflect total activity required to manufacture a given product; the Producer Price Index for all industrial commodities was used to deflate dollars to a common base year (1982). Finally, data for industries producing similar products were grouped. The actual groupings used here are included in the following analysis of each primary product type.

VALUE-ADDED METHOD FOR EVALUATING ECONOMIC BENEFITS

A relative measure of the contribution of the manufacturing process to the value of the final product is the ratio of the value added from manufacturing to the value of industry shipments. This ratio of value-added to value of shipments will always be between 0 and 1, and it can be used to compare activity within the industry over time or activity between industries. A high ratio (close to 1.00) indicates that the manufacturing process contributes more to the value of the final product than the cost of the raw materials. A low ratio indicates that the cost of the raw materials, not the manufacturing process, largely determines the value of the products. Thus, the higher the ratio, the larger the relative contribution of the industry to the economy--a larger proportion of the value of shipments is derived from the actual manufacturing process.

The ratio of value-added to value of shipments is developed for each primary product. This ratio is used to evaluate and recommend the product with the greatest potential for increasing the value of the timber resource.

PRIMARY TIMBER PROCESSING

Primary timber processing includes the harvesting and removal of timber from the forest, and the conversion of this timber into primary products. The primary timber processing activities considered here are (1) timber harvesting, (2) lumber manufacturing, (3) plywood and veneer manufacturing, (4) composite wood panel manufacturing, and (5) treated wood product manufacturing.

Timber Harvesting

The harvesting and removal of timber from the forest is the first step in utilizing the timber resource. In this report, timber harvesting includes SIC Industry 2411--Logging. In 1987, 11,721 establishments were primarily engaged in harvesting and removing timber from U.S. forests (Table 1). These establishments tended to be small; only 7 percent had 20 or more employees. Total employment was 87,000, with a payroll of $1.5 billion ($10^9$). Shipments were valued at $11.1 billion; $4.2 billion was value-added.

Over the last 15 years, the value of shipments has ranged from a low of $6.8 billion in 1975 to the current high of $11.1 billion; value-added has ranged from a low of $2.5 billion in 1982 to the current high of $4.2 billion. In fact, 1987 was the first year in that decade that shipments and value-added exceeded previously recorded highs.

In 1988, the ratio of value-added to value of shipments for timber harvesting was 0.38. From 1972 to 1987, the ratio averaged 0.39. Thus, stumpage and other costs accounted for over 60 percent of the value of the timber harvested; less than 40 percent was directly attributable to the actual harvesting process.

Lumber Manufacturing

Lumber manufacturing includes SIC Industries 2421--Sawmills and Planing Mills, 2426--Hardwood Dimension and Flooring Mills, 2429--Special Product Sawmills, and 2439--Structural Wood Members. These industries all produce lumber and other related sawnwood products for sale. A total of 7,508 establishments produced lumber or related products in 1987 (Table 1). Like timber harvesting establishments, lumber manufacturing establishments tended to be small; only a third of these establishments had 20 or more employees. Employment was 203,100, and the payroll exceeded $3.6 billion. Shipments were valued at $20.6 billion; $8.3 billion was value-added.

Lumber manufacturing, like timber harvesting, has fluctuated widely over the last 15 years. Shipments and value-added during the last decade did not reach record levels set in the late 1970s.

The ratio of value-added to value of shipments for lumber manufacturing in 1987 was 0.40. This has been the average ratio since 1972. Lumber manufacturing is very similar to timber harvesting in that about 60 percent of the value of the products manufactured is derived from the cost of the materials used in the manufacturing process, and just 40 percent is derived from the manufacturing process itself.

Plywood and Veneer Manufacturing

Plywood and veneer manufacturing includes manufacturers of all types of hardwood and softwood plywood panels and veneer (Industries 2435--Hardwood Veneer and Plywood, and 2436--Softwood Veneer and Plywood). It does not include nonveneered structural panels made from wood flakes, wafers, or strands, such as oriented strandboard or waferboard. These nonveneered, reconstituted wood panels are included in composite wood panels. Although there were only 540 plywood and veneer manufacturing establishments in 1987 (Table 1), these establishments tended to be large, and nearly 75 percent of them had 20 or more employees. Total employment in 1987 was 58,800, and the payroll was nearly $1.1 billion. Plywood and veneer shipments were valued at $6.2 billion, and value-added was $2.4 billion.

As with other primary timber processors, wide fluctuations in value indicators have been experienced in plywood and veneer manufacturing. Record levels of shipments and value-added achieved in the 1970s have not yet been regained.

In 1987, the ratio of value-added to value of shipments for plywood and veneer manufacturing was 0.38, the same as the ratio for timber harvesting. The average ratio for plywood and lumber manufacturing since 1972 has been slightly lower--0.36. Thus, plywood and veneer manufacturing is similar to timber harvesting and lumber manufacturing in the relative contribution of the manufacturing process to the economy.

Composite Wood Panels Manufacturing

Composite wood panels manufacturing is a newly formed industry in the SIC system (Industry 2493--Reconstituted Wood Products). It consists of a variety of composite panel products, including particleboard, waferboard and oriented strandboard, medium density fiberboard, hardboard, and insulation board. The growth in manufacturing in these products and the need to better classify establishments that produce these products resulted in the formation of the industry in the 1987 SIC revision. Data prior to 1987 for this group of products, except particleboard, are therefore not available.

In 1987, 253 establishments produced composite wood panels in the United States (Table 1). Nearly two-thirds of these establishments had 20 or more employees. Employment was 22,100, and payroll exceeded half a billion dollars. Shipments were valued at $2.9 billion; value-added was $1.4 billion.

In 1987, the ratio of value-added to value of shipments for composite wood panels manufacturers was 0.48, indicating that nearly half the value of the finished product was derived from the manufacturing process. From 1972 to 1982, the ratio for particleboard producers alone averaged 0.44.

Treated Wood Products Manufacturing

Treated wood products manufacturing includes establishments that preserve both roundwood and sawnwood with a variety of chemical treatments. A total of 526 establishments preserved wood in 1987 (Table 1). Of these, 199 establishments had 20 or more employees. Employment was 11,500, and the payroll exceeded $200 million. Shipments were valued at $2.1 billion; $0.5 billion was value-added.

Treated wood manufacturing, unlike the manufacturing of many other primary products, has grown fairly consistently during the last 15 years in terms of the total value of industry shipments. Nevertheless, value-added peaked in 1978.

In 1987, the ratio of value-added to value of shipments for treated wood manufacturing was 0.25, considerably below the 15-year average of 0.32. This indicates that although products shipments have been increasing in value, the cost of raw materials has been increasing at a faster rate.

CONTRIBUTIONS OF PRIMARY TIMBER PROCESSING TO THE ECONOMY

In aggregate, the primary timber processing defined here is an important component of the U.S. economy. In 1987, the 20,548 establishments in operation provided 382,300 jobs, had a $7.0 billion payroll, and produced products valued at $43.3 billion. Value added in the manufacturing process totaled $16.8 billion. This information not only verifies the importance of these manufacturers to the economy, but it also provides insight into ways to increase their contribution.

Many localities, regions, and nations, particularly developing nations, have abundant timber resources but limited processing facilities. Timber is harvested and exported directly to other localities or regions within the country or to other countries for further processing. Attempts to improve the economy often include increasing timber harvest to create jobs and to increase cash flow into the economy. The increased supply of logs resulting from increased harvesting may actually depress log prices, while at the same time reducing the resource base for future harvests. The net addition to the economy may be small and well below desired levels.

Another approach to stimulating a timber-based economy is to process the harvested timber into primary timber products before exporting to other localities, regions, or countries. This further processing will increase the value of the timber, provide new jobs, and help maintain the timber base. The ratio of value-added to value of shipments for primary timber processing in the United States in 1987 can be used to help guide the choice of which primary processing activities should be developed. The ratios for primary processing industries are as follows:

Primary processing industry	Ratio of value-added to value of shipments
Lumber	0.40
Plywood and veneer	0.38
Composite wood panels	0.48
Treated wood products	0.25

The further processing of timber into lumber, plywood, and veneer, reconstituted wood products, or treated wood would all substantially increase the value of the harvested timber. Although these ratios for primary processing industries are based on aggregate data and do not necessarily correspond to activity within individual establishments, they do indicate that the manufacturing of composite wood panels generally adds more value to the resource than does the manufacturing of other primary products. Nearly half the value of composite wood panels is directly attributable to the manufacturing process. Only a quarter the value of treated wood products is attributable to the manufacturing process. Lumber manufacturing and plywood and veneer manufacturing are intermediate in their addition of value to the resource. Thus, a mill producing $10 million of composite wood panels annually would add $4.8 million to the value of the resource, value which would be lost were the resource exported for further processing.

CONCLUSION

The wise use of the forest resource can provide employment and income to local, regional, and national economies. The processing of harvested timber into primary products, such as lumber, plywood, composite wood panels, or treated wood products, can further increase employment and income while retaining the integrity of both the resource and other forest-related activities. Of the principal primary timber products, the manufacturing of composite wood panels adds substantially more value to the timber resource, and hence to the economy, than the manufacturing of other primary products. Composite wood panels manufacturing therefore provides the opportunity to add more value to the timber resource, on the average, than other types of primary processing. Thus, to improve the economy and better utilize the timber resource, the manufacturing of composite wood panels should be considered first when selecting a manufacturing process.

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Table 1.--Economic indicators for primary timber processing in the United States, 1972-87[a]

Year	Manufacturing establishment				Value of products ($\times 10^6$ US\$)		Ratio of value-added to shipment value
	Total number	Number with $\geq$ 20 employees	Number of employees ($\times 10^3$)	Payroll ($\times 10^6$ US\$)	Value added	Value of shipments	
				TIMBER HARVESTING			
1987	11,721	818	87.0	1,548.6	4,163.4	11,064.9	0.38
1986	--	--	72.3	1,285.7	2,965.5	8,444.2	0.35
1985	--	--	76.3	1,248.7	2,918.8	8,445.0	0.35
1984	--	--	84.7	1,338.8	2,888.1	8,831.4	0.33
1983	--	--	83.5	1,313.0	2,785.7	8,746.0	0.32
1982	11,658	657	80.8	1,220.6	2,528.2	8,361.1	0.30
1981	--	--	85.8	1,242.5	2,698.9	8,405.5	0.32
1980	--	--	96.5	1,399.2	3,553.1	9,541.3	0.37
1979	--	--	90.4	1,490.2	4,105.2	9,881.9	0.42
1978	--	--	87.2	1,654.9	3,868.7	10,165.5	0.38
1977	15,469	708	83.3	1,604.3	3,845.8	9,905.9	0.39
1976	--	--	71.5	1,361.7	3,709.3	7,614.8	0.49
1975	--	--	67.2	1,199.0	3,092.8	6,837.2	0.45
1974	--	--	75.5	1,345.3	3,657.8	7,431.7	0.49
1973	--	--	85.9	1,443.7	3,850.8	7,982.3	0.48
1972	13,238	696	80.0	1,434.7	3,185.9	6,926.8	0.46
				LUMBER MANUFACTURING			
1987	7,508	2,446	203.1	3,637.4	8,258.1	20,633.3	0.40
1986	--	--	187.0	3,287.6	7,082.5	18,075.6	0.39
1985	--	--	180.2	3,002.0	5,762.1	15,416.8	0.37
1984	--	--	185.8	2,951.0	5,839.5	15,481.3	0.38
1983	--	--	183.5	2,883.3	5,659.1	15,057.5	0.38
1982	8,107	2,099	170.0	2,536.4	4,151.0	12,207.2	0.34
1981	--	--	203.6	2,891.5	5,209.5	14,410.0	0.36
1980	--	--	223.2	3,204.8	6,285.1	16,602.0	0.38
1979	--	--	240.9	3,780.0	8,766.6	21,039.6	0.42
1978	--	--	228.3	3,782.1	9,046.7	21,318.8	0.42
1977	9,656	2,498	225.1	3,632.5	8,109.5	19,531.7	0.42
1976	--	--	219.7	3,365.5	7,317.3	16,860.3	0.43
1975	--	--	205.1	2,958.6	5,519.3	13,483.6	0.41
1974	--	--	233.3	3,362.0	7,275.0	16,125.2	0.45
1973	--	--	226.6	3,813.5	9,613.0	20,390.6	0.47
1972	10,129	2,363	217.1	3,904.6	8,468.4	18,950.2	0.45

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Table 1.--Economic indicators for primary timber processing in the United States, 1972-87[a]--con.

	Manufacturing establishment				Value of products ($\times 10^6$ US$)		
Year	Total number	Number with ≥ 20 employees	Number of employees ($\times 10^3$)	Payroll ($\times 10^6$ US$)	Value added	Value of shipments	Ratio of value-added to shipment value
			PLYWOOD AND VENEER MANUFACTURING				
1987	540	402	58.8	1,097.3	2,401.0	6,249.7	0.38
1986	--	--	52.9	1,010.0	2,134.9	5,528.9	0.39
1985	--	--	53.0	959.4	1,833.4	5,015.7	0.37
1984	--	--	55.8	973.6	1,697.7	5,062.8	0.34
1983	--	--	57.4	959.9	1,720.0	5,093.5	0.34
1982	556	412	52.7	834.7	1,179.6	4,169.3	0.28
1981	--	--	62.1	949.7	1,454.3	4,962.6	0.29
1980	--	--	65.5	1,021.6	1,723.5	5,470.7	0.32
1979	--	--	71.8	1,246.5	2,360.5	7,055.6	0.33
1978	--	--	70.2	1,316.1	3,128.2	8,017.0	0.39
1977	577	451	68.5	1,264.5	2,993.6	7,587.5	0.39
1976	--	--	66.9	1,144.5	2,601.1	6,586.9	0.39
1975	--	--	61.7	1,000.8	1,871.8	5,173.4	0.36
1974	--	--	68.2	1,108.8	2,072.0	5,650.0	0.37
1973	--	--	70.5	1,331.1	3,149.7	7,247.0	0.43
1972	598	479	68.8	1,413.2	3,170.8	7,263.3	0.44
			COMPOSITE WOOD PANELS MANUFACTURING				
1987	253	157	22.1	513.8	1,395.1	2,919.3	0.48
1986	--	--	--	--	--	--	--
1985	--	--	--	--	--	--	--
1984	--	--	--	--	--	--	--
1983	--	--	--	--	--	--	--
			Particleboard Only				
1982	54	50	5.6	105.6	195.3	553.1	0.35
1981	--	--	5.1	90.5	217.3	552.1	0.39
1980	--	--	5.4	96.9	245.5	583.7	0.42
1979	--	--	6.0	111.8	334.0	706.0	0.47
1978	--	--	6.7	135.0	493.1	938.2	0.53
1977	63	51	6.2	127.0	332.7	727.2	0.46
1976	--	--	5.6	105.7	211.8	540.1	0.39
1975	--	--	5.5	96.6	156.9	461.5	0.34
1974	--	--	7.5	127.5	315.7	684.8	0.46
1973	--	--	7.6	151.4	479.0	861.7	0.56
1972	68	64	7.7	161.0	355.3	726.2	0.49

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Table 1.--Economic indicators for primary timber processing in the United States, 1972-87[a]

	Manufacturing establishment				Value of products ($\times 10^6$ US$)		
Year	Total number	Number with ≥ 20 employees	Number of employees ($\times 10^3$)	Payroll ($\times 10^6$ US$)	Value added	Value of shipments	Ratio of value-added to shipment value
			TREATED WOOD PRODUCTS MANUFACTURING				
1987	526	199	11.5	201.1	533.1	2,106.8	0.25
1986	--	--	11.1	184.5	513.7	1,807.7	0.28
1985	--	--	11.1	182.0	520.3	1,665.5	0.31
1984	--	--	10.7	169.0	487.5	1,600.3	0.30
1983	--	--	10.2	156.9	336.9	1,389.1	0.24
1982	524	184	10.9	162.7	391.7	1,388.5	0.28
1981	--	--	12.3	180.0	435.3	1,440.9	0.30
1980	--	--	13.2	192.3	507.0	1,575.5	0.32
1979	--	--	12.9	197.0	505.3	1,597.1	0.32
1978	--	--	12.9	204.3	554.1	1,676.1	0.33
1977	457	192	12.6	194.3	504.0	1,483.2	0.34
1976	--	--	9.7	155.6	377.1	1,159.8	0.33
1975	--	--	9.3	151.7	395.8	1,122.9	0.35
1974	--	--	10.6	178.2	621.3	1,449.4	0.43
1973	--	--	10.1	171.1	424.3	1,269.6	0.33
1972	399	168	11.3	193.0	455.5	1,232.8	0.37

Source: U.S. Department of Commerce (1985,1989).

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MINERAL BONDED WOOD COMPOSITES:
EMERGING TECHNOLOGIES

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SUMMARY

When particles or fibers of wood or recycled fiber are held together with a mineral matrix, such as portland cement or gypsum, a composite is formed that can be used in a variety of structural an industrial applications. These composites offer unique advantages over conventional building materials. Some are water resistant and durable in the outdoor applications. Almost all are fireproof or highly fire-resistant, insect and rot resistant.

These composites combine the characteristics of their components namely wood (or recycled fiber) and the mineral matrix.

This presentation reviews the history and the present status of these emerging technologies around the world and in North America. The basic concept will be briefly explained followed by the modern industrial practices currently in effect in manufacturing these composites. Both cement and gypsum bonded composites incorporating wood residue and recycled fiber will be discussed. The presentation also deals with the emerging market opportunities in North America and covers some of the applications of these materials. Key advantages in the raw material and product properties will be noted.

Keywords: Particleboard, gypsum, portland cement, mineral composites

INTRODUCTION

Particles or fibers of wood held together with an inorganic matrix, such as portland cement or gypsum, form a composite that can be used in a variety of structural and industrial applications. These composites offer unique advantages over conventional building materials. Some are water resistant and can withstand rigors of the outdoor applications. Almost all are either fireproof or highly fire resistant.

These composites combine the characteristics of their components, namely wood and the mineral matrix.

The concept of combining inorganics with wood or agricultural biomass is very old. Incorporating wheat or rice straw with mud to produce bricks has its roots in prehistory (9). Such mineral bonded composites are still used in many parts of the world. Mixing straw with mud improves workability and reduces fracture development by utilizing a reinforcing fiber.

Modern mineral-bonded wood composites date back to the turn of the century. Table 1 traces the development of these composites. The early magnesite bonded boards were generally of low quality because the magnesite matrix was very sensitive to moisture (9). Cement-bonded excelsior boards, developed later, had better water resistance. The industrial application of pressure to produce cement bonded particleboard did not occur until about the mid-1930's. With the gradual evolution of the resin-bonded particleboard technology, much was learned that also applies to mineral-bonded composite panels.

TABLE 1. Industrial production of inorganic-bonded wood composites (6)

Year	Products
1900	Magnesite-bonded boards
1905	Gypsum-bonded excelsior board
1915	Gypsum plasterboard
1915	Magnesite-bonded excelsior board
1927	Cement-bonded excelsior boards
1937	Molded wood-cement products
1942	Resin-bonded particleboards
1965	Cement-bonded wood composite panels
1972	Gypsum fiberboards (shredded paper)
1972	Magnesite-bonded wood composite panels
1982	Gypsum particleboard

During the nineteen fifties and sixties, a considerable amount of research and development was carried out by Elmendorf Research, Inc. (ERI), on cement-bonded panel product development in the United States. I was involved in some of this work. We combined two concepts: cement bonding and wood particle orientation. This work led to the production of a structural composite of superior properties (3,4). The wood particle orientation concept resulted in the later development of resin-bonded oriented structural board (OSB), which is now being used widely in the North America.

Early Industrial production of cement-bonded particleboard panels was based on ERI patents (3,4). In 1965, panels were produced in Japan based on those patents.

WOOD-CEMENT COMPOSITES

The basic concept involves the incorporation of wood particles or fibers into a cement matrix. In composites often referred to as cement-bonded particleboard, particles of wood, such as sawdust or flakes, are used. Theoretically, many different types of material can be incorporated with the cement matrix, including recycled paper fiber or other recyclable wastes, a substantial portion of which is currently going into landfills in the U.S. and other countries.

A great lack of knowledge surrounds the various aspects of wood-cement composites. This is also true of other types of mineral-bonded wood or wood fiber composites, in part because manufacturing experience is not as extensive as that of resin-bonded particleboard. In fact, very little activity has taken place in this field in North America, although that is likely to change in the near future.

A major positive factor in wood-cement composite technology is based, in part, on the fact that needed raw materials, namely cement, wood (or agricultural biomass), are extensively available. Therefore, countries lacking resin production facilities can manufacture cement-bonded particleboard. Additives such as calcium chloride or sodium silicates are often available locally or can be imported at relatively low cost.

Manufacture

Currently, cement-bonded particleboard panels are manufactured in relatively small plants. Plant capacities of 15 to 110 million square feet (3/4-inch basis) are common. This compares with capacities of 140 to 550 million square feet (3/4-inch basis) for resin-bonded particleboard plants. This smaller capacity is due to the technological requirements associated with cement hardening and curing. These plants are largely based on the basic concepts expressed in the ERI patents of 1965-66. Most cement-bonded particleboard plants require clamping boards to be cured for 6 to 8 hours at about 80 degrees C before they can be further processed. Due to curing rate of cement, additional 18 to 20 days is needed before the boards can be shipped.

The smaller plant size for cement-bonded board, however, is not necessarily a disadvantage because of the need to "localize" market ranges, thereby avoiding long-distance shipping of relatively heavy panels. Although the plant does not require particle drying or sophisticated resin blenders, it does require curing chambers and specialized clamping devices for the cold pressing operation.

Figure 1 outlines a typical cement-bonded particleboard manufacturing process. Wood is reduced to the desired particle size by flakers or other types of reduction units. Screening devices segregate the particles into the desired sizes. No drying is required at this stage. The basic components of the composite, such as wood, cement and water, are added together to make a relatively dry furnish ready for forming into a mat. A number of these mats are then stacked on caul plates to be clamped by a specially designed clamping device. After clamping, the assembly is transferred to the curing chamber for setting. After the curing stage, the clamps are opened and boards trimmed and placed in the yard for additional curing. Conditioning, sizing and finishing can then take place before the boards are shipped to customers.

Recent technology developed in Europe treats the composite with Co2 gas. This, it is claimed, brings about a number of advantages, including a short press time (4.5 minutes), a closer thickness tolerance, manufacture of thin boards down to 4 mm, and a simpler flow process due to no need for clamping devices used in conventional technology. Recent reports suggests that the

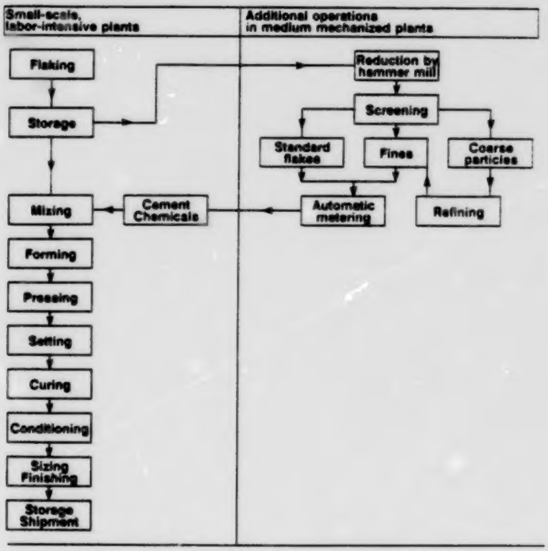
Small-scale, labor-intensive plants
Additional operations in medium mechanized plants
Flaking
Storage
Mixing
Forming
Pressing
Setting
Curing
Conditioning
Sizing Finishing
Storage Shipment
Cement Chemicals
Reduction by hammer mill
Screening
Standard flakes
Fines
Coarse particles
Automatic metering
Refining

Figure 1. Outline of the steps in the manufacturing process for cement bonded particleboard.

press time may be further reduced to possibly one minute. This technology will enable the construction of large capacity plants similar to those producing resin bonded particleboard. The fast curing process also permits the use of hardwoods and other species that may prove troublesome with the long cure time.

Raw Material Influences

The influence of the wood raw material on board properties in manufacturing cement-bonded particleboards is of critical importance under present technology. We, at the University of Idaho, have done a considerable amount of work on wood-cement compatibility (6,8). Figures 2 and 3 show that adding wood particles to cement alters the cement's hydration pattern. These figures illustrate that hardwoods generally inhibit cement hydration more than softwoods. This is due to the large amount of hydrolyzable hemicellulose in hardwoods. The alkaline medium produced by cement dissolves the extractives and hemicellulose which, in turn, react as retardants to cement. Water extraction often significantly improves wood-cement compatibility, as it does the use of additives.

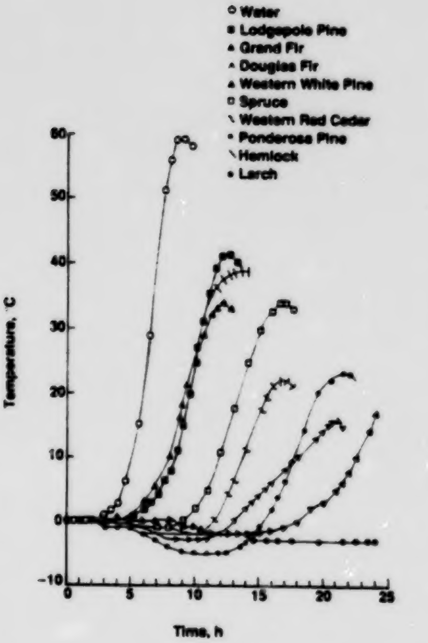

Figure 2. Hydration characteristics of portland cement when mixed with nine northern Rocky Mountain wood species.

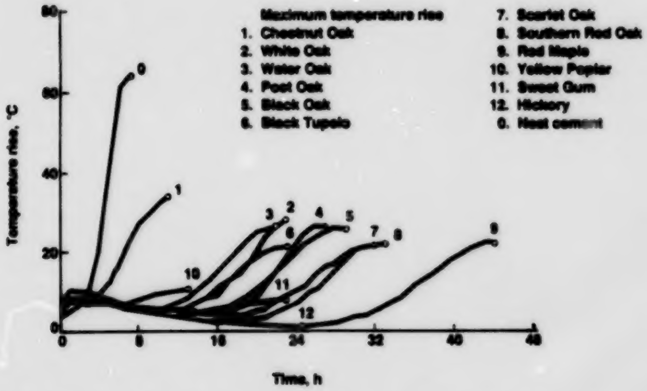

Figure 3. Effects of 12 wood species on hydration of portland cement with untreated samples ($n = 4$)

Under current industrial practice, wood raw material is stored for 3 to 4 months or longer (depending on the wood species being used and the location of the plant) to equalize the moisture and reduce the amount of extractives and hemicellulose. Thus, factories need a wood inventory and adequate land area for a wood yard.

The wood raw material can be virtually in any form, including roundwood, pulp chips, planer shavings, sawdust or other forms of residue. If engineered particle sizes are to be used, the larger pieces of wood raw material would be needed. For example, flake-like particles can not be produced from sawdust.

The relationships between particle geometry and final board properties that apply in the case of resin-bonded particleboard also generally apply to cement-bonded particleboard. Thus, cement-bonded boards could be produced with certain properties through the manipulation of particle geometry, among other raw material and manufacturing parameters.

Portland cement, the other key ingredient in the cement-bonded particleboard technology, can substantially influence the final board properties and has a major impact on the economics of manufacture. Although composition can vary from plant to plant and from country to country, silicates form a major component of composition. Table 2 shows that 75 percent of cement is composed of di- and tri-calcium silicates. Although current commercial boards do not utilize cross-orientation of wood particles, such cross-orientation is possible in a 3-layer board. In such a board configuration, the particles are aligned parallel to each other on the surface layers, but the core or middle layer particles can be oriented in a perpendicular direction. When this construction is combined with the use of flake-like particles, board properties are enhanced as compared to randomly layered smaller particles.

TABLE 2. The basic composition of portland cement

Chemical Name	Chemical formula	Weight percent
Tricalcium silicate	$3CaO.SiO_2$	50
Dicalcium silicate	$2CaO.SiO_2$	25
Tricalcium aluminate	$3CaO.Al_2O_3$	12
Tetracalcium aluminoferile	$4CaO.Al_2O_3$	8
Calcium sulfate dihydrat	$CaSO_4.2H_2O$	3.5

Board Properties and Application

Cement-bonded particleboard properties offer a variety of advantages. One of these is excellent machinability, enabling the manufacturer or the user to incorporate intricate cuts and joints. This can facilitate the development of a process by which V-shaped grooves can be cut into flat panel surfaces. The use of special adhesives enables the manufacturer to produce panels with flanges. This configuration enables builders to combine studs, sheathing and siding into single panels. House construction utilizing this type of technology is taking place in a number of countries where such panels are put into place vertically and bolted together for quick assembly.

In addition to home construction, cement-bonded particleboard is used in non-residential construction in a number of applications. These include prefabricated housing, cladding, balcony parapets and floors. Cement-bonded panels can be used in industrial walls, sound barriers, garden and fence walls, as a replacement for asbestos boards and treated plywood, and as a substitute for all-weather wood foundations.

For interior applications, cement-bonded particleboard can be used in partitions, non-flammable walls and ceilings, nonflammable furniture, shielding for steel supports, lining for high humidity rooms and bathroom tile backing.

Cement-bonded particleboard offers properties that, in some respects, are unique. Important attributes include high fire resistance, exterior durability, moisture resistance, sound proofing, and rot and insect resistance. In addition, this composite does not contain any hazardous chemicals and will not release any type of gases, such as is the case for resin-bonded particleboards. Thus, this material does not adversely affect interior air quality.

Table 3 provides a comparison of some of the important strength properties for cement-bonded particleboard as compared with some of the other panel products. As this table shows, cement-bonded particleboards generally have a lower modulus of rupture than resin-bonded particleboard, but are superior in modulus of elasticity.

TABLE 3. Comparison of strength properties of cement- and gypsum-bonded boards with those of plasterboard and resin-bonded particleboard

	Gypsum-bonded Particle board	Cement-bonded Particle board	Gypsum Fiber board	Gypsum Plaster board	Resin-bonded Particle board
MOr, psi	900-1500	1350-2250	750-1100	450-1200	1800-3500
MOe, 1000 psi	300-520	450-900	370-520	300-600	300-520
Internal bond, psi	45-90	60-105	45-75	30-45	75-150
Tensile strength in board plane, psi	375-600	600-750	220-450	220-450	1050-1500
Density, pcf	68-75	68-80	68-75	50-55	40-47

A major advantage of cement-bonded particleboard is the ability to withstand outdoor exposure. These panels have performed well in accelerated weathering tests. Research in England exposing small panels to cycles of 72 hours of soaking in water, 24 hours of freezing at -12 degrees C and 72 hours of drying at 70 degrees C demonstrates that these boards easily pass British Standards (2). Additional data on production samples that were exposed to the outdoors in 1977 in England and others exposed in West Berlin, show excellent performance. In these tests, the boards retained their original strength well over a number of years of test exposure. To be sure, additional data over longer periods of time are needed to more accurately assess the outdoor durability of cement-bonded particleboards.

An important factor in outdoor durability is the ability of the board to maintain a low level of dimensional change with environmental humidity fluctuations. Commercial cement-bonded particleboards exhibit excellent thickness stability and acceptable linear expansion characteristics. However, considerable differences exist in these properties in boards made by different manufacturers. Linear dimensional change could vary considerably from manufacturer to manufacturer, depending on the degree of control exercised by the managers of a given operation to produce quality boards and the type of technology employed in plant construction. Considerable reduction in linear dimensional change could be achieved with the use of particle geometries and the proper use of felting (forming) devices and techniques.

WOOD-GYPSUM COMPOSITES

Wood-gypsum composites, as defined in this paper, refer to gypsum fiberboard and particleboards. Table 1 shows that both of these types of board material are of relatively recent origin. Gypsum fiberboards, using recycled (shredded) paper, date back to 1972, while gypsum particleboard came into production as recently as 1982.

Gypsum Fiberboard and Particleboards

The production of gypsum fiber and particleboards provide an alternative to the traditional production of gypsum board (sheet rock) manufacture. The incorporation of wood particles and fibers impart advantages that give these boards a certain degree of practical importance in Europe. These technologies are beginning to appear in the United States and Canada where plants are either under construction or have been announced.

Comparisons are often made between these technologies and that producing the traditional gypsum board. The traditional gypsum board (sheetrock) has been produced by the "wet" process. A relatively large amount of water is used in this process (approximately 4 to 6 times the water needed for the hydration of the gypsum). In some of the processes, glass fiber mat or short glass fibers are used to improve the properties of the resulting panel material. Light pressure sometimes is applied to induce a smoother surface, but significant consolidation is not possible due to the high water content of the mat.

Short glass fibers are utilized to reduce brittleness; but significant improvement in the strength does not take place with the addition of such fibers (11). The high cost of glass fiber can adversely impact the economics of this process.

The basic concept of this composite material involves the incorporation of wood fibers (generally in the form of shredded paper) into a gypsum matrix. These processes generally use limited amounts of water adequate for the hydration of the gypsum within a relatively short time.

The Wurtex Process

The Wurtex process is described in some detail in this section as an example of gypsum fiberboard technologies. The raw material involves gypsum and paper fiber. Gypsum (calcium sulphate hemihydrate) can come from one of three sources. It can come directly from mining the material from numerous natural sources available around the world. The other source involves the REA gypsum which is formed during the desulfurization process in fossil-fuel-fired power plants. The third source of gypsum is the byproduct of acid production plants, sometimes referred to as chemical gypsum. The latter often involves more cleaning and processing than either natural gypsum or flue gas gypsum. In any event, gypsum is calcined to form plaster, the material used in the gypsum fiberboard process.

The fiber used is generally newsprint shredded through bale shredders, hammer mills and fiber mills. In some of the processes, the conversion of wastepaper into usable fiber is accomplished in three steps: Consolidating the paper, reducing the material to postage-size pieces, and fiberizing the pieces. Precautions must be taken to keep fire hazard low because shredded paper is very combustible at this stage of the production process. Figure 4 illustrates one example of gypsum fiberboard manufacturing process known as the Wurtex process.

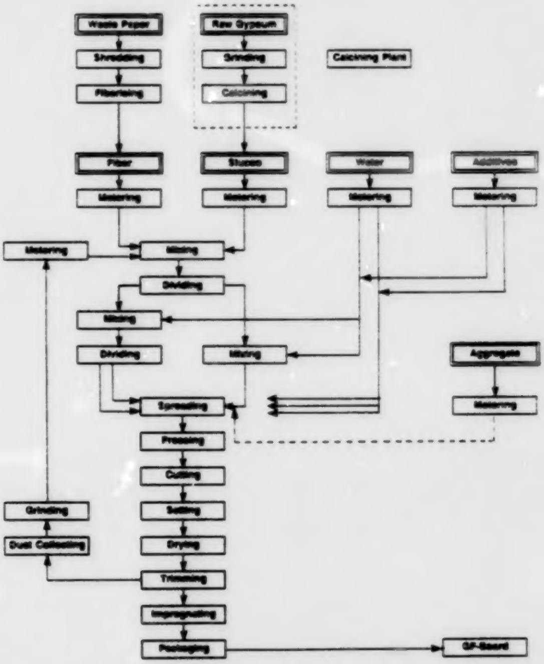
Waste Paper
Raw Gypsum
Shredding
Grinding
Calcining Plant
Fiberizing
Calcining
Fiber
Stucco
Water
Additives
Metering
Metering
Metering
Metering
Metering
Mixing
Dividing
Mixing
Dividing
Mixing
Aggregate
Spreading
Metering
Pressing
Cutting
Grinding
Setting
Dust Collecting
Drying
Trimming
Impregnating
Packaging
GF-Board

Figure 4. The basic flow diagram for the Wurtex gypsum fiberboard process.

Fiberized wastepaper is then sent to a mixer to be mixed with gypsum, water and additives. The mixing of the water with the mixture is very tricky and if inappropriately done, can cause "balling" and otherwise uneven mixing. In the Wurtex process, the needed water is partially added during this mixing process, with the remaining portion added between the forming and the pressing operation (7).

The additives regulate the setting time for gypsum. Ideally, gypsum setting should take place during the board consolidation in the press. Gypsum hydration should be completed during the same period.

In the Wurtex process, current plant operation involves mixing two batches: one intended for the core layer; the other, divided into two streams, directed to the board surfaces. In some processes, the three-layer board is constituted such that the core layer is substantially made from a different type of furnish than that making up the surfaces. For example, perlite or other inorganic materials can be incorporated into the core layer to reduce weight and bring the density down by 30 percent or more. With this concept, density can be reduced, for example, from 1250 kg/m3 to about 850 kg/m3.

It is important to position the furnish mixers as close to the formers as possible. Forming is done by three spreading machines: one deposits the bottom surface, another deposits the core layer, and the final spreading head lays down the top surface to complete the forming process. Before, during, and after the forming process, the remaining water is added in measured quantities so that adequate water is available at the right time for gypsum hydration. In some of the processes, the moisture added is calculated such that approximately 15 percent moisture remains in the board prior to the board entering the dryer. Less water reduces board strength. Using more water than necessary raises the cost of drying.

At this point in the process, the setting time of gypsum is very rapid, normally in the range of 20 to 30 seconds. Due to the rapid-setting nature of gypsum, continuous pressing of the boards is the best way to consolidate the mat. Special synthetic belts come in contact with the board during the pressing process. The press pressure is considerably lower than the pressure used to manufacture the resin-bonded particleboard. During the pressing operation, the limited amount of water that is added does not result in excess water being squeezed out. In some of the processes, one of the belts used during the pressing consists of a sieve to allow air to escape from the mat during the consolidation of the board in the press.

Upon exiting the press, the boards are cut to size, often by a water jet. The trimmings are recycled back into the process, with the material often incorporated with the furnish used in the board's core layer.

The setting of gypsum continues after the pressing is completed and prior to drying. It is important to allow sufficient time between the press and the dryer because once the moisture is reduced during the drying process, additional setting essentially ceases. Generally speaking, approximately 20 minutes should elapse in this stage in the Wurtex process, depending on the type of gypsum used and the calcining utilized. Jet dryers are used for plants currently operating with the drying time of about 30 minutes for a board thickness of 10 mm. Clearly, thicker boards require a longer press time. Upon exit, the boards have a moisture content of about 1 percent (7). In some plants a silicone type of coating is applied to protect the boards against accidental exposure to water. The annual production of a Wurtex process plant can range from 5.5 to 11 million m2 at a 10mm thickness.

Other Processes:

A number of other processes have been developed using gypsum and wood fibers or particles. In the following section, some of these are described briefly.

Processes that have gained importance in Europe in recent years are the Babcock-BSH Process, Kossatz-Bison Process, Schenck Process, and the Siempelkamp-Feramcell Process (11).

The Babcock-BSH process is a "wet" process producing a slurry with gypsum and paper fibers in a fiber-gypsum suspension. In this process, the powder gypsum is mixed with fibers and water to form the slurry. The mat is formed with this slurry. The mat is then densified, dewatered and sectioned into separate boards. The boards are calcined (dehydrated), then rehydrated with an autoclave. The consolidated boards are then dried and finished, if desired.

The Kossatz-Bison is a semi-dry process of manufacturing a gypsum-bonded particleboard. In this process, wood flakes are mixed with a predetermined amount of water. The water/binder ratio typically ranges from 0.35 to 0.40. The wet flakes are then mixed with the gypsum in a mixer to form the relatively dry furnish. At this stage, the furnish is ready for forming. Single boards are on separate cauls. These boards are then stacked in a special clamping device to be solidified under pressure. The gypsum binder is set in the clamp in a relatively short time. The boards are later removed from the clamp and dried. Trimmings are recycled. Capacity of such a plant can range to 5 million m2 per year (10mm thickness).

The Schenck process is a semi-dry process that utilizes recycled fiber. The water/gypsum ratio in this process ranges from 0.4 to 0.5. The fibers are incorporated with a predetermined amount of water into which gypsum and additives are mixed. The relatively dry furnish is then formed into a continuous mat and directed into a continuous press. The Schenck process produces a three-layer board designed to reduce the weight of the panel. In this case, the core layer is separately handled and involves lower density materials.

Once the continuous ribbon emerges from the press, it is cut into the desired size and directed to a dryer. The annual capacity of plants producing this type of board can range from 3 to 4 million m2.

The Siempelkamp/Fermacel process also relies on recycled fiber and gypsum. The fiberized paper is moistened and incorporated with the gypsum. The dry furnish is then formed into mats with additional water. A vacuum system is used to partially dewater the mat, with the water/binder ratio at this stage reaching about 0.50. The ribbon of mat is cut into separate boards and allowed to set without the application of pressure. Drying, finishing steps are then followed. Manufacturing plants capacity may range from 3 to 11 million m2 per year.

At this writing, at least 9 countries manufacture gypsum fiberboard. Gypsum fiberboard has claimed approximately 15 percent of the West German market. Gypsum particleboard began production in October 1985 in Finland. A second plant in Norway is also reported to be running smoothly and producing 60,000 tons per year.

Both gypsum particleboard and fiberboard are extremely fire resistant. They also exhibit good soundproofing qualities and excellent dimensional stability. They do not have any formaldehyde release. Due to their superior properties, as compared to sheetrock, jointless assembly without the need to apply tape is possible. They can be overlaid easily with veneers or other types of overlaying material. Production of a wide range of thicknesses is possible. For example, the production of very thick boards presents no technological problem because the boards set by an exothermic process.

Product applications are considerably more varied than with standard gypsum board. Flooring, soundproofing, dry wall applications, furniture applications, and paneling are some examples. The primary disadvantage of these boards is their higher density in some forms. In this area, producing a 3-layer board with low density materials in the core, as noted earlier, has succeeded in reducing density.

RELATED TECHNOLOGIES

A number of technologies, either developed or in the process of refinement, combine wood particles or fibers with a mineral matrix. Some of these have had a long history.

One of these involves the use of magnesium oxyphosphates (10). This mineral cement readily bonds with lignocellulosic materials. The mixture of wood particles or fibers of practically any species can be used because the reaction is self-initiating, exothermic and is not affected by the free water soluble sugars and extractives in wood. The setting of the composite is rapid, allowing continuous press operation. The magnesite-bonded wood composite is highly fire-resistant and resistant to water and outdoor elements. However, the material is expensive and the process is very sensitive to variations. Recent work suggests, however, that up to 75 percent of magnesite may be substituted with dolomite without significant loss in board strength and water resistance. Dolomite is considerably less expensive than magnesium oxyphosphate cement (10).

The Ecocem process, developed in Finland, is based on the use of alkali-activated, ground-granulated blast furnace slag as the binder-matrix (1). This is a rapidly setting binder-matrix that can utilize technology similar to that used for the production of resin-bonded particleboard. The process, due to its rapid setting characteristics, is capable of utilizing any type of wood species. It has been suggested that currently available but unprofitable conventional particleboard plants can be retrofitted for the production of this material. The properties of the Ecocem boards are similar to those of cement bonded particleboard. The board is hot pressed. Table 4 shows the basic chemical composition of the blast furnace slag. Table 5 shows the some of the important board properties of the board.

TABLE 4. The chemical composition of blast furnace slag (1).

Component	Weight percent
CaO	34-46
S_1O_2	34-48
Al_2O_3	8-13
MgO	6-12
Fe_2O_3	0.2-2.7
Na_2O	0.7-0.9
K_2O	0.1-0.9
SO_3	0.6-2.0

TABLE 5. Properties of slag-wood board (Ecocem) (1)

Density (Kg/m^3	1.333
Moisture content	8.0
Modulus of rupture (MPa)	10.1
(after V313 weather test (MPa))	6.9
Internal bond (MPa)	0.84
(after V313 weather test (MPa))	0.35
Thickness swelling (24 hr., %)	1.3
Residual thickness swell after V313 weather test (%)	0.7
Linear expansion (35-90% RH)	0.25

CONCLUSIONS

Clearly, the technologies that combine wood with non-wood materials will increasingly be utilized to produce composites for an increasingly sophisticated marketplace. In addition, developing environmentally safe technologies will be of greater importance in the years ahead. Consumers will look for affordable, nonhazardous materials. Fire, insect and rot resistance will also be very important to builders and consumers. The opportunity to take advantage of the increasing volumes of wastepaper and other recyclables will be with us for many years.

Mineral-bonded wood composites offer opportunities to respond to these trends. Made of safe and durable materials, they can be engineered to meet the needs of specific market niches. The wood raw material could be either recycled newspaper or low-grade wood residue. Non-commercial wood species and very low-grade, nonmerchantable wood are prime raw material. For many countries that wish to conserve their hard currencies, these composites can be made of local raw material and would provide products that can meet many building needs and desires of the local culture.

In North America, these technologies appear to be slowly claiming their rightful place among the family of building materials technologies for a variety of applications. Initial market research information indicates acceptance for many uses in both the United States and Canada. Mineral-bonded wood composites are becoming universal in meeting the building and industrial needs in both the developed and the developing countries.

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CHEMICAL MODIFICATION OF WOOD: ITS APPLICATION TO COMPOSITE WOOD PRODUCTS

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FDC: 813.1: 842: 862

ABSTRACT

The performance properties of composites made from wood and other lignocellulosic materials can be greatly improved by changing the basic chemistry of the cell wall polymers. This paper covers the research that has been done to improve dimensional instability and susceptibility to degradation by biological organisms, heat, and ultraviolet radiation to produce high-performance wood composites based on acetylation of the furnish before product formation.

INTRODUCTION

For the most part, composites can be broken down into two basic types: price-driven composites, for which costs dictate the markets, and performance-driven composites, for which properties dictate the markets. A few composites might be of both types, but usually these two types are very different.

In general, the wood composite industry has produced price-driven composites. Even though the wood composite industry is growing, it has lost some market share to competing materials such as steel, aluminum, plastics, and glass. Unless something is done to improve woods competitive performance, opportunity for growth will be limited in the future.

Wood, and other lignocellulosic materials, are three-dimensional, polymeric composites made up primarily of cellulose, hemicellulose, and lignin. These polymers make up the cell wall and are responsible for most of the physical and chemical properties of these materials. Wood and other lignocellolosic materials have been used as engineering materials because they are economical, low in processing energy, renewable, and strong. They have however, several undesirable properties, such as dimensional instability due to moisture sorption with varying moisture contents, biodegradability, flammability, and degradability by ultraviolet light, acids, and bases. These properties are all the result of chemical reactions involving degradative environmental agents. Because these types of degradation are chemical in nature, it should be possible to eliminate them or decrease their rate by modifying the basic chemistry of the cell wall polymers.

Two properties which have restricted wood from high performance composites are dimensional instability both in thickness and in linear swelling and shrinking and biodegradation. By using cell wall chemical modification technology, dimensionally stable, biologically resistant wood furnish can be produced. Recent research at the Forest Products Laboratory has concentrated on acetylation as the chemical modification technique on fiber, particles, chips, and flakes (Rowell et al 1986). While dimensionally stable wood composites have been made from these acetylated furnishes, the ultimate goal of the research is to produce formable/shapable composite materials.

The acetylation of wood fiber has the potential of producing a furnish which can be formed into nearly unlimited shapes which are smooth, dimensionally stable, and biologically resistant. Such technology, though higher in basic cost, can compete in performance-driven markets. A stabilized wood fiber can also be mixed with other stable materials such as metals, plastic, and glass to produce new composites in such a way that a synergism between the materials results in a composite that is better than the individual components.

We have developed a simple acetylation process using uncatalyzed acetic anhydride with no additional co-solvents (Rowell et al 1986, 1989b). The following data was derived from wood veneers, flakes, particles, and fiber acetylated using this procedure.

MOISTURE SORPTION

Sorption of moisture is mainly due to hydrogen bonding of water molecules to the hydroxyl groups in the cell wall polymers. By replacing some of the hydroxyl groups on the cell wall polymers with acetyl groups, the hydroscopicity of the lignocellulosic material is reduced.

Table 1 shows the fiber saturation point (FSP) and equilibrium moisture content (EMC) of aspen and southern pine at various relative humidities (RH). It can be seen that both FSP and EMC are greatly reduced as the level of acetylation is increased. Earlier results showed that the bonded acetate was mainly in the lignin and hemicelluloses (Rowell 1982) and that isolated wood cellulose does not react with uncatalyzed acetic anhydride (Rowell unpublished data). Because acetate is found mainly in the lignin and hemicellulose polymer, and because isolated cellulose does not acetylate by the procedure used, acetylation may be controlling the moisture sensitivity due to the lignin and hemicellulose polymers in the cell wall but not reducing the sorption of moisture in the cellulose polymer.

TABLE 1. Fiber Saturation Point (FSP) and Equilibrium Moisture Content (EMC) of control and acetylated aspen and southern pine flakes

Sample	Weight Gain	Fiber Saturation Point	Equilibrium Moisture Content at 27 °C			
			30%RH	65%RH	80% RH	90%RH
	%	%				
Aspen	0	46	4.9	11.1	15.3	21.5
	8.7	29	3.1	7.7	10.2	14.9
	13.0	20	2.0	5.9	8.2	11.8
	17.6	15	1.6	4.8	6.7	9.4
Southern Pine	0	45	5.8	12.0	16.2	21.7
	6.0	24	4.1	9.2	12.8	17.5
	10.4	16	3.3	7.5	10.3	14.4
	14.8	15	2.6	6.0	8.8	11.6
	18.4	14	2.3	5.0	7.1	9.2
	21.1	10	1.7	4.3	6.1	8.1

DIMENSIONAL STABILITY

Dimensional instability, especially in the thickness direction, is a great problem in wood composites because they not only undergo normal swelling (reversible swelling) but also swelling caused by the release of residual compressive stresses imparted to the board during the composite pressing process (irreversible swelling). Water sorption causes both reversible and

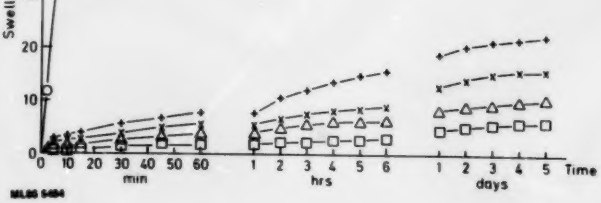

FIGURE 1--Rate of swelling in liquid water of aspen flakeboard made from control and acetylated flakes. O - control; + - 7.3 WPG; X - 11.5 WPG; Δ - 14.2 WPG; □ - 17.9 WPG. (ML85 5494).

irreversible swelling with some of the reversible shrinkage occurring when the board dries.

The rate of swelling in liquid water of an aspen flakeboard made from acetylated flakes and phenolic resin (Rowell 1986) is shown in Figure 1. During the first 60 min, control boards swelled 55% in thickness while the board made from flakes acetylated to 17.9 WPG swelled less than 2%. During 5 days of water soaking, the control boards swelled over 66% while the 17.9 WPG board swelled about 6%.

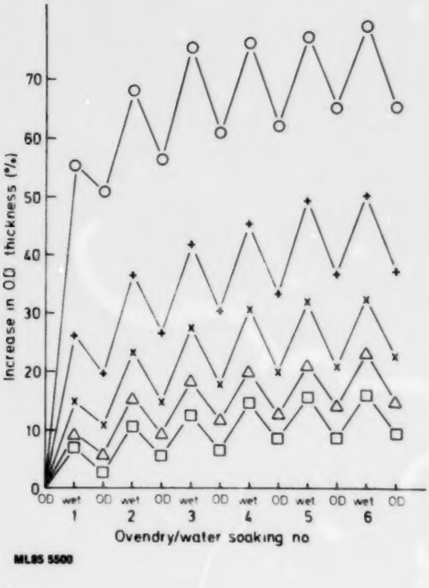

FIGURE 2--Changes in ovendry (OD) thickness in repeated water-soaking test of aspen flakeboard made from acetylated flakes. 0 = control; + = 7.3 WPG; X = 11.5 WPG; △ = 14.2 WPG; □ = 17.9 WPG. (ML85 5500)

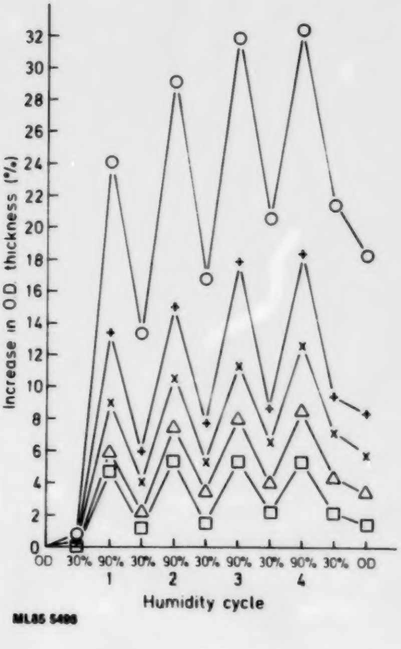

FIGURE 3--Changes in ovendry (OD) thickness at 30% and 90% relative humidity of aspen flakeboard made from acetylated flakes (27°C). 0 = control; + = 7.3 WPG; X = 11.5 WPG; △ = 14.2 WPG; □ = 17.9 WPG. (ML85 5496)

Thickness changes in a six-cycle water-soaking/ovendrying test for an acetylated aspen flakeboard are shown in Figure 2 (Rowell 1986). Control boards swelled over 70% in thickness during the 6 cycles as compared to less than 15% for a board made from acetylated flakes. Acetylation greatly reduced both irreversible and reversible swelling.

Figure 3 shows changes in thickness of aspen flakeboards made from control and acetylated flakes using a phenolic adhesive at different relative humidities (Rowell 1986). After four cycles of 30% to 90% RH, control boards swelled 30% in thickness while acetylated boards at 17.9 WPG swelled about 5%.

The results of both liquid water and water vapor tests show that acetylation of wood furnish greatly improves dimensional stability of composites made from these materials.

BIOLOGICAL RESISTANCE

Chemical modification of wood composite furnish for biological resistance is based on the theory that the potentially degrading enzymes must directly contact the substrate, and the substrate must have a specific chemical configuration and molecular conformation. Reacting chemicals with the hydroxyl groups on cell wall polymers chemically changes the substrate so that the highly selective enzymatic reactions cannot take place. Chemical modification also reduces the moisture content of the cell wall polymers to a point where biological degradation cannot take place.

Particleboards and flakeboards made from acetylated flakes have been tested for resistance to several different types of organisms. In a 4-week termite test using Reticulitermes flavipes (subterranean termites), boards acetylated at 16 to 17 WPG were very resistant to attack, but not completely so (Rowell et al 1987, 1988a). This may be attributed to the severity of the test. However, since termites can live on acetic acid and decompose cellulose to mainly acetic acid, perhaps it is not surprising that acetylated wood is not completely resistant to termite attack.

Chemically modified wood composites have been tested to decay fungi in several ways. Untreated aspen and pine particleboards and flakeboards exposed to white-, soft-, and brown-rot fungi and tunneling bacteria in a fungal cellar were destroyed in less than 6 months while particleboards and flakeboards made from acetylated furnish above 16% acetyl weight gain showed no attack after 1 year (Table 2, Rowell et al 1987, 1988a, Nilsson et al 1988).

In a standard 12-week single-culture soil-block test, control aspen flakeboards exposed to the white-rot fungus Trametes versicolor lost 34% weight, while acetylated flakeboards (17% acetyl weight gain) lost no weight (Rowell et al 1987, 1988a, Nilsson et al 1988). Using the brown-rot Tyromyces palustris, control aspen flakeboards lost only 2% weight when a phenol-formaldehyde adhesive was used but lost 30% weight when an isocyanate adhesive was used. If the flakeboards are water leached before the soil-block test is run, control boards made with phenol-formaldehyde adhesive lose 44% weight with the brown-rot fungus *Gloeophyllum trabeum* (Rowell et al 1987).

TABLE 2. Fungal cellar tests on aspen flakeboards from control and acetylated flakes[a,b]

Acetyl	Rating at intervals[d]					
WPG[c]	2 mo	3 mo	4 mo	5 mo	6 mo	12 mo
0	S/2	S/3	S/3	S/3	S/4	--
7.3	S/0	S/1	S/1	S/2	S/3	S/4
11.5	0	0	S/0	S/1	S/2	S/3
13.6	0	0	0	0	S/0	S/1
16.3	0	0	0	0	0	0
17.9	0	0	0	0	0	0

[a] Nonsterile soil containing brown-, white-, and soft-rot fungi and tunneling bacteria.

[b] Flakeboards bonded with 5% phenol-formaldehyde adhesive.

[c] Weight percent gain.

[d] Rating system: 0 - no attack; 1 - slight attack; 2 - moderate attack; 3 - heavy attack; 4 - destroyed; S - swollen.

This shows that the adhesive can influence results of fungal toxicity, especially in a small, closed test container.

Weight loss resulting from fungal attack is the method most used to determine the effectiveness of a preservative treatment to protect wood composites from decaying. In some cases, especially for brown-rot fungal attack, strength loss may be a more important measure of attack since large strength losses are known to occur in solid wood at very low wood weight loss (Cowling 1961). A dynamic bending-creep test has been developed to determine strength losses when wood composites are exposed to a brown- or white-rot fungus.

Using this bending-creep test on aspen flakeboards, control boards made with phenol-formaldehyde adhesive failed in an average of 71 days with *T. palustris* and 212 days with *T. versicolor* (Rowell et al 1988b). At failure, weight losses averaged 7.8% for *T. palustris* and 31.6% for *T. versicolor*. Isocyanate-bonded control flakeboards failed in an average of 20 days with T. palustris and 118 days with T. versicolor, with an average weight loss at failure of 5.5% and 34.4%, respectively (Rowell et al 1988b). Very little or no weight loss occurred with both fungi in flakeboards made using either phenol-formaldehyde or isocyanate adhesive with acetylated flakes. None of these specimens failed during the test period.

Deflection-time curves for flakeboards are shown in Figure 4. There was an initial increase of deflection for both control and acetylated flakeboards, then a stable zone, and, finally, for control boards a steep slope to failure. The study showed that less than 5 mm of deflection was caused by creep due to moisture alone (Rowell et al 1988b).

Mycelium fully covered the surfaces of isocyanate-bonded control flakeboards within 1 week, but mycelial development was significantly slower in phenol-formaldehyde-bonded control flakeboards. Both isocyanate- and phenol-formaldehyde-bonded acetylated flakeboards showed surface mycelium colonization during the test time, but the fungus did not attack the acetylated flakes so little strength was lost.

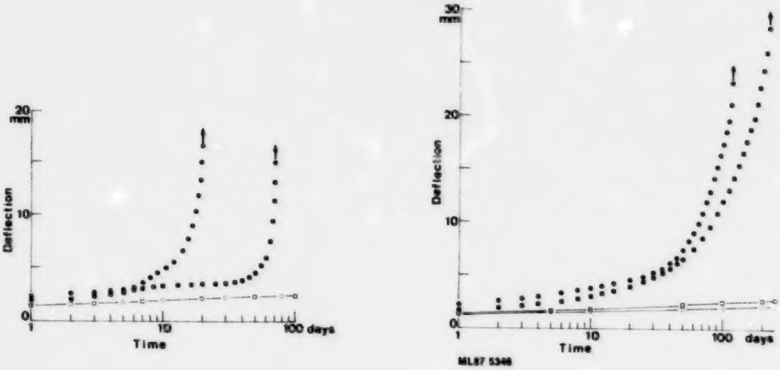

FIGURE 4--Deflection-time curves of phenol-formaldehyde (PF)- and isocyanate (IS)-bonded flakeboards in bending-creep tests under progressive fungal attack by T. palustris (left) and T. versicolor (right). ■ - PF control; □ - PF acetylated; ● - IS control; o - IS acetylated. (ML87 5346)

In similar bending-creep tests, both control and acetylated pine particleboards made using melamine-urea-formaldehyde adhesive failed because T. palustris attacked the adhesive in the glueline (Imamura et al 1988). Mycelium invaded the inner part of all boards, colonizing in both wood and glueline in control boards but only in the glueline in acetylated boards.

After a 16-week exposure to T. palustris, the internal bond strength of control aspen flakeboards made with phenol-formaldehyde adhesive was reduced over 90% and that of flakeboards made with isocyanate adhesive was reduced 85% (Imamura et al 1987). After 6 months of exposure in moist unsterile soil, the same control flakeboards made with phenol-formaldehyde adhesive lost 65% of their internal bond strength and those made with isocyanate adhesive lost 64% internal bond strength. Failure was due mainly to great strength reductions in the wood caused by fungal attack. Acetylated aspen flakeboards lost much less internal bond strength during the 16-week exposure to T. palustris or 6-month soil burial. The isocyanate adhesive was somewhat more resistant to fungal attack than the phenol-formaldehyde adhesive. In the case of acetylated composites, loss in internal bond strength was mainly due to fungal attack in the adhesive and moisture, which caused a small amount of swelling in the boards.

Acetylated pine flakeboards have also been shown to he resistant to attack in a marine environment (Johnson and Rowell 1988). Control flakeboards were destroyed in 6 months to 1 year, mainly because of attack by Limnoria tripunctata, while acetylated boards showed no attack after 2 years.

All laboratory tests for biological resistance conducted to this point show that acetylation is an effective means of reducing or eliminating attack by soft-, white-, and brown-rot fungi, tunneling bacteria and subterranean termites. Tests are presently underway on several lignocellulosic composites in outdoor environments.

OTHER PROPERTY IMPROVEMENTS

There are other properties of lignocellulosic composites that can be improved by changing the basic chemistry of the furnish (Rowell 1984). Acetylation has been shown to improve ultraviolet resistance of aspen veneers. Table 3 shows that acetylataion greatly reduced weight loss, errosion rate, and the depth of penetration of ultraviolet degradation due to loss of surface fiber from aspen veneers (Feist et al In Press). The rate of errosion for

TABLE 4. Weight loss and erosion of modified aspen after 800 hours of accelerated weathering.

Specimen	Weight loss %/hr	Erosion µ/hr	Reduction in Erosion[a] %	Depth of Penetration of Weathering[b] µm
Control	0.0194	0.121	-	189-210
Acetylated	.0095	.059	51	84-105

[a] Compared to control
[b] Measured in cross section

boards made from acetylated veneers is half that of control veneers. In outdoor tests after two years, flakeboards made from acetyalted pine flakes are still light yellow in color while control boards have turned dark orange to light gray during this time.

Acetylation does not change the fire properties of wood. In thermogravametric analysis, acetylated and control pine sawdust pyrolyze at the same temperature and rate (Rowell et al 1984). The heat of combustion and rate of oxygen consumption are also the same for control and acetylated specimens showing that the acetyl group added to the cell wall has approximately the same carbon, hydrogen and oxygen content as the cell wall polymers. Reactive fire retardants can be bonded to the cell wall hydroxyl groups. The effect would be an improvement in dimensional stability, biological resistance as well as fire retardancy.

The acoustical properties of acetylated veneer are greatly improved over control veneers (Norimoto et al 1988). This finding has lead to the commerical production of high performance stero speakers in Japan.

USES

In recent advancements, technology has been developed to form acetylated high yield whole wood fiber into flexible mats using either a non-woven needling technique or a thermoplastic fiber welding technique. These fiber mats can be impregnated with an adhesive (such as a powdered phenolic resin) at the time the mat is formed and pressed into many different shapes. This fiber mat technology allows the formation of a final product of uniform all density directly from the wood fiber.

Products made thus far from this acetylation fiber technology show (1) high dimensional stability both in the thickness and lineal directions, (2) high level of rot resistance, (3) low degree of thermal expansion, (4) smooth surfaces that do not require further sanding, (5) uniform density throughout the product wall, (6) no increase in toxicity of the wood, (7) high strength - both wet and dry, (8) high degree of ultraviolet radiation stability, and (9) no change in flamibility.

Acetylated veneers can be pressed along with the acetylated fiber mat to yield veneer faced fiber backed products (Rowell et al 1989a). Other face materials can also be used such as metals, plastics, glass or synthetic fibers.

A few of the products that are now under consideration include (1) interior automobile moldings both for insulation and shaping, (2) interior automotive structural materials, (3) dash boards and decorative automotive trim (using a modified veneer face), (4) exterior door skins for home construction, (5) exterior window skins and whole window units, (6) exterior cladding for home construction, (7) furniture, both veneer faced and fiber molded, (8) color stable veneered paneling, (9) circuit boards, (10) deep drawn materials for containers, (11) flooring, and (12) reusable packaging.

COST

An economic/engineering analysis of producing acetylated veneer, particles and fiber shows a cost of about 10 to 11 cents per pound to acetylated these furnishes (Power 1989). The cost to produce the acetylated fiber mat adds about 5 cents per pound. The cost of the acetylated fiber mat at roughly triple the price of unacetylated fiber directs this technology into value added products where markets are driven by performance rather than cost alone. In considering cost, it must be remembered that it is possible to produce the final product from the fiber mat technology so the price already includes much of the secondary manufacturing cost.

SUMMARY

Properties such as dimensional instability and susceptibility to degradation by biological organisms, and ultraviolet radiation can be greatly improved by modification of wood cell wall polymers. These modifications result in a furnish that can be converted into composites of any desired shape, density and size, and provide an opportunity for a manufacturer to distinguish a product line based on quality, uniformity, and performance. Of the various reaction systems studied to date, a simple noncatalyzed acetylation process appears to be closest to implementation on a commercial basis.

Composites made from wood furnishes have been restricted from many markets mainly because of their moisture sorption, dimensional instability and to a lesser entent due to their biological degradation. These negative properties can be overcome allowing veneers, flakes, particles and fiber from wood residues to find markets in high performance composites.

For some applications, the optimum composite may be a combination of other materials to achieve the desired properties and performance. Future research will be directed at combining stabilized acetylated fiber with other fibers and veneers made from glass, metals, synthetic fibers and other biomass fibers and with acetylated wood veneers. The ultimate goal of this research program is to produce formable/shapable composite materials. We will be studying the formation of flexible fiber mats both by nonwoven needling and thermoplastic fiber melt metrix technologies to produce complex shaped high performance composites.

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COMPOSITE PRODUCTS FROM NON--WOOD FIBROUS RAW MATERIALS

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SUMMARY

After analyzing the needs of developing composite products from non-wood fibrous raw materials in China, this paper presents some research work done recently at CRIWI regarding manufacture of composite products from bamboo, flax, bagasse, cotton stalk, reed, soyabean stalk and tobacco stalk etc. It is found that these raw materials are suitable for making composite boards, which can be used for many applications as substitutes for composite boards made from wood raw materials. The future for developing non-wood fibrous composite products in China is promising.

Keywords: non-wood, composite products

1. INTRODUCTION

China is a densely populated country with highly insufficient forest resources. The growing tree stock per capita is only about 8 cubic meters which is over thirteen times less than the world's average. In recent years, 300 million cubic meters of timber are used up and the average deficit of forest resoruces reaches 170 million cubic meters. Mature forests have been reduced by half in the country's 131 forest bureaux over the past 10 years. Experts predict that nearly half the country's 4,000 tree farms will have no timber at all by the turn of the century. The development of the national economy and the improvement of the people's standard of living requires even larger supplies of wood. It is estimated that the gap between annual supply and demand of industrial timber will reach about 50 million cubic meters by the end of the century.

China, currently the world's second largest timber importer ranking only behind Japan, in 1987 imported approximately 10 million cubic meters of timber. Although Chinese import demand for timber is likely to increase, China faces a number of constraints to increase its supply from external sources, such as restricted availability of hard currency and producing countries' trend to limit log exports etc.

An important way to alleviate this situation is to develop composite products with emphasis on particleboard, made from non-wood fibrous raw materials, which are abundant in China, apart from establishing more fast-growing tree plantations and developing better and integrated utilization of the available supply of wood raw materials.

The manufacture of particleboard made from plant materials other than wood started in 1940's. The European countries were the first to take an interest in these materials, and in Belgium, for example, particleboard made from flax represented some 70 % of a very considerable panel production. It was reported that on an overall basis,non-wood plant fibrous represent about 3.5 % of the total fibrous raw materials for all reconstituted panelboard, and about 5 % of the world's particleboard capacity is based on non-wood plant fibers, mainly flax, bagasse, hemp, jute sticks etc. It is found that their characteristics are not fundamentally different from those of wood based particleboards. Rice husks, wheat straw, groundnut shells, and bamboo, etc. are also used for manufacture of particleboard.

The non-wood fibrous raw material resources are quite rich in China, the annual output of bamboo is about 4 million tons and that of agriculture plant stalks can reach 400 million tons, which are not well utilized. If 5 % of these raw materials could be used, 20 million cubic meters of panel products can be produced, which is equivalent to 60 million cubic meters of logs and equals to the annual production of timber within the Chinese central government plan.

The development of composite products from non-wood fibrous raw materials will be of great economic and social importance in China.

2. COMPOSITE PRODUCTS FROM SEVERAL NON-WOOD FIBROUS RAW MATERIALS

A lot of research work has been done at CRIWI in recent years on manufacture of composite products from non-wood fibrous raw materials, such as bamboo, flax, cotton stalks, bagasse, soyabean stalks, wheat straw, millet straw, corn stalks, reed, and tobacco stalks, etc. The preliminary results are briefly introduced as follows.

2.1 Particleboard

2.1.1 Particleboard based on bamboo

Bamboo is composed of fibers, parenchyma, vessels and phloem. With average fiber length (L) of 2.5 mm, dimension width (W) 13 micron, the size of fiber is between that of softwood and hardwood. The slenderness ratio L/W equals to 115-290, usually more than 150; Runkel ratio 2T/I [T----cell wall thickness, I---- lumen width] is bigger than 1, both ratios are more than double of that of wood. In chemical composition, the cellulose content is about 49-58 %, lower than that of wood; semicellulose content 20-33 %, similar to that of hardwood and much more than that of softwood; lignin content 21-28 %, close to that of hardwood and lower than that of softwood; contents of solubilities, sugar and protein are higher than that of wood; ash content is about 0.8-3.2 % and silica content is high. After air drying, the moisture content of bamboo is about 14-18 % with density 0.7-0.84 g/cm3 and the strength properties of bamboo are higher than that of most wood species.

Without radial cell elements, bamboo is easy to be crushed and converted into uniform particles. The outermost skin, which is covered by a cutinized layer with a wax coating, and the innermost side, which is covered by a layer of sclerenchyma cells, can not be bonded satisfactorily with UF adhesives. But this can be improved by converting bamboo into needle type particles since the surface ratio of the outermost skin and the innermost side in bamboo particles is reduced. The compression ratio [density of bamboo / density of panel] was 1:1.1-1.2, as the density of bamboo is quite high.

The specific parameters used in this study can be summarized as follows:

Species:	Sinocalamus affinis Pleiblastus amarus
Mat structure:	3 layers
Core / face:	65 :35
UF resin content (%)	10-12
Hardener (NH4CL %):	3
Wax content (%):	1
Press temperature (Celsius):	180
Press time (s):	72-240
Board thickness (mm):	6-19

Properties of particleboard from bamboo showed as follows:

Thickness (mm):	6	8	12	19
Density (g/cm3):	0.72	0.73	0.68	0.70
Bending strength (MPa):	32.3	34.3	29.9	36.9
Tensile strength perpendicular to surface (MPa):	1.06	1.38	0.93	0.99
Thickness swell (%):	5.8	4.0	3.2	1.9
Modulus of elasticity (MPa):	3,298	3,840	3,273	3,532
Moisture content (%):	5.5	5.2	5.2	5.2

It should be pointed out that the resin content and/or density of boards in this study could be further reduced to a lower level.

2.1.2 Flaxboard

The raw material for a flaxboard plant is a by-product of the preparation of flax fiber, being the woody portion of the plant remaining after separation from the fibers. During the fiber-separation operation, the lignous portion is broken into pieces of 0.2 to 1.7 cm long and 0.1 to 2.5 mm wide which constitute the shives. The impurities found with the shives consist of 5 % tow, 2 % sand and 12 to 15 % roots. The roots can be used as raw materials after milled while tow and sand have to be discarded. After screening, the portion screened through 0.3 mm and retained on 8 mm were discarded; the material that passed through 8 mm and retained on 2 mm screen was used for core layer while that passed through 2 mm and retained on 0.3 mm screen was milled and used for face layer. With moisture content usually less than 15 %, the shives for face can be used directly without drying.

Panel manufacturing conditions were as follows:

Moisture content of particles (%):	5 for core 10 for face
Mat structure:	3 layers
Core / face:	65:35
UF resin content (%):	5 for core 10.7 for face
Hardener (NH4CL) (%):	1.5 for core 0 for face
Wax content (%):	1.5
Thickness of board (mm):	7.5
Press temperature (Celsius):	180-190
Press pressure (MPa):	3.5
Press time (min):	3.5

Properties of flaxboard showed as follows:

Density (g/cm3):	0.61
Bending strength (MPa):	19.9
Tensile strength perpendicular to surface (MPa):	0.58
Thickness swell (%):	5
Moisture content (%):	3.3

2.1.3 Particleboard based on wheat straw

Particleboard based on wheat straw cannot be made satisfactorily with conventional aqueous adhesives. Polyisocyanates are used in some countries for bonding this kind of material but the cost is high. A kind of modified UF resin, named IMNY-1 multi-component adhesive developed by CRIWI, was used in the study of making wheat straw particleboard without adding any hardener and water repellent.

Panel manufacturing conditions were:
Moisture content of particles (%): 2-4
Mat structure: 3 layers
Core /face: 65/35
Resin content (%): 14
Thickness of panel (mm): 12
Press temperature (Celsius): 180
Press pressure (MPa): 3.5
Press time (min): 7

Properties of particleboard based on wheat straw were:
Density (g/cm3): 0.52-0.66
Bending strength (MPa): 18.5-31.8
Tensile strength perpendicular to surface (MPa): 0.39-0.56
Thickness swell (%): 4.2-6
Moisture content (%): 4.2-7.8

Further research is being carried out at CRIWI to reduce resin content and press time.

2.1.4 Particleboard based on sunflower stalks

Sunflower stalk contains large portion of pith, which is a kind of porous material having strong ability of water absorption and should be removed. By air shifting and screening the dried particles from sunflower stalks, pith can be removed and discarded.

Panel manufacturing conditions were:
Moisture content of particles (%): 3-3.5
Mat structure: 3 layers
Core /face: 65/35
Thickness of panel (mm): 19
UF resin content (%): 8.5 for core
12 for face
Hardener (NH4CL %): 1.0
Wax content (%): 0
Press temperature (Celsius): 180
Press pressure (MPa): 3.5
Press time (min): 6

Properties of particleboard based on sunflower stalks were:
Density (g/cm3): 0.65
Bending strength (MPa): 20.6-22.3
Tensile strength perpendicular to surface (MPa): 0.46-0.52

Thickness swell (%):	8.4-11.9

Further research is needed to reduce the thickness swell and the press time.

2.1.5 Particleboard based on corn stalks

Compared with wood, corn stalk has lower portion of cellulose and lignin, high portion of semicellulose and ash, and lower fiber strength.

Panel manufacturing conditions in this study were:

UF resin content (%):	10-12
Hardener (NH4CL %):	0.5-2.5
Wax content (%):	0-1.6
Panel thickness (mm):	4-12
Press temperature (Celsius):	145-155
Press time (min):	3-8

Properties of particleboard based on corn stalks were:

Density (g/cm3):	0.6-0.8
Bending strength (MPa):	16-22
Tensile strength perpendicular to surface (MPa):	0.5-0.8
Thickness swell (%):	4-6

2.1.6 Particleboard based on millet straw

Experiments showed that millet straw is suitable for manufacture of particleboard, but further research should be done to improve its thickness swell property.

Panel manufacturing conditions were:

UF resin content (%):	10-12
Wax content (%):	0-1.
Hardener (NH4CL %):	0.5-2.5
Panel thickness (mm):	4-12
Press temperature (Celsius):	145-155
Press pressure (MPa):	2.5-3.5
Press time (min):	3-8

Properties of particleboard based on millet straw were:

Density (g/cm3):	0.6-0.8
Bending strength (MPa):	16-19
Tensile strength perpendicular to surface (MPa):	0.6-0.8
Thickness swell (%):	8-12

2.2. Medium Density Fiberboard (MDF)

The characteristics of non-wood fibrous raw materials should be taken into consideration when making MDF from these kinds of materials, such as bamboo, cotton stalk, bagasse and reed etc.

Cotton stalk is mainly composed of fibers, vessels and parenchyma cells and has half-lignification characteristic. The fiber content is more than 50 %, thickness of cell wall 2 micron, lumen's diameter 12 micron, ratio of fiber length and width 30 which is just as same as that of hardwood and smaller than that of softwood. In chemical composition, the holocellulose content is about 70 %, pentosan content 16-19 %, lignin content 20 %, extractive content 9-15%. The density is lower than wood's.

Bagasse is mainly composed of vascular bundles containing lignin, fiber cells, parenchyma vessels. The fiber length is about 0.6-0.8 mm, width 16-30 micron, which is close to that of hardwood. The holocellulose content is about 74.5 %, pentosan content 25.2 % , lignin content 18.9 % , protein content 0.8 %, cold-water extractive content 5.2 %, hot- water extractive content 6.9 % and bagasse's ph value 5.6. Bagasse takes 10 to 13 percent weight of sugar cane and 50 percentage of bagasse is sugar cane skin which is composed of smooth, tightly ranged fiber cells and epidermis. In bagasse there is also 15 to 28 percentage of sugar cane pith which is soft parenchyma ground tissue.

Reed is mainly composed of stalk, leave sheath and pith. Reed stalk's holocellulose content is about 71.4 % , pentosan content 23.8 %, lignin content 19.4 %, hot-water extractive content 6.6 % and reed stalk's ph value is 4.7. The reed leave sheath's chemical composition is not much different from that of stalk's. The leave sheath's holocellulose content is about 68.2 %, pentosan content 21.6 , lignin content 19.8 %, hot-water extractive content 10.5 % and its ph value is 4.7.

The green covering of bamboo and sugar cane skin are difficult to be preheated, resulting in much more power consumption and poor pulp quality in defibering. Non-wood fibrous raw materials, such as cotton stalk, bagasse and reed etc. , have lower bulk density and swell significantly after soaking, which reduces the efficiency of defibrator.

The experimental parameters of manufacturing MDF based on above four kinds of non-wood fibrous raw materials were as follows:

Chip steaming pressure (MPa):		0.6-0.8
Preheating time (min):		3-7
Freeness (s):		16-20
UF resin content (%):		12
Wax content (%):		1.0-2.0
Mat moisture content (%):		11-15
Press temperature (Celsius):		70-180
Press pressure (MPa):	1st stage	3.5-4.0
	2nd stage	2.0
	3th stage	1.5
Press time (min/mm thickness of panel):		0.8-0.9

The main physical and mechanical properties of non-wood MDF were as follows:

Raw materials:	Cotton stalk		bamboo	Reed	Bagasse
Thickness (mm):	18	9	9	9	9
Density (g/cm3):	0.65-0.69	0.70-0.75	0.70-0.75	0.72-0.76	0.70
Bending strength (MPa):	30-40	32-36	25	26-30	30-35
Internal bonding (MPa):	0.50-0.60	0.60-0.65	0.50	0.45-0.55	0.60-0.65

Thickness swell (%):	6-8	8-10	9	7-8	4-6
Linear expansion (%):	0.30-0.40	0.35-0.50	0.30	0.30-0.38	0.30

2.3 Hardboard

The technological parameters and main physical and mechanical properties of hardboards based on soyabean stalk and tobacco stalk were as follows.

Technological parameters:

Raw materials:		Soyabean stalk	Tobacco stalk
Chip steaming pressure (MPa):		0.4-0.5	0.5
Preheating time (min):		3-4	5
Freeness (s):		20-25	16
Wax content (%):		2-3	2-3
PF resin content (%):		0.5-1.0	0.5-1.0
Board thickness (mm):		3.5	3.0
Press temperature (Celsius):		195-205	190-200
Press pressure (MPa):	1st stage	6.5	6.5
	2nd stage	0.5	0.5
	3th stage	6.5	6.5
Press time (s):		500-620	390

Main physical and mechanical properties:

Raw materials:	Soyabean stalk	Tobacco stalk
Density (g/cm3):	0.94-1.00	0.94
Bending strength (MPa):	27.4-35.8	42.5
Water absorption (%):	29-43	28.5
Moisture content (%):	4.5-5.4	

3. CONCLUSION

The research results showed that non-wood fibrous raw materials, such as bamboo, flax, cotton stalk, bagasse, corn stalk, wheat straw, sunflower stalk, millet straw, reed, soyabean stalk and tobacco stalk, are suitable for manufacturing composite products whose physical and mechanical properties behave like wood-based panels. These non-wood fibrous raw materials do not have much difference in chemical components from that of wood's, but have their own characteristics indeed, such as lower density (except bamboo), lower bulk density, more impurities, higher semicellulose contents, lower lignin contents, higher protein, starch and sugar contents etc., resulting in not only difficulties in collection and storage but also degradation caused by fungi and insects. The top wax coating existing in green covering of bamboo and wheat straw has serious effects on gluability of particles. There are large quantities of pith in bagasse, flax, sunflower and corn stalk , that caused composite products made from them high water absorption, poor water resistance, high thickness swelling and low bonding strength. But these situations can be improved by technology and equipment modifications . For example , bamboo's gluability can be improved by converting bamboo into needle type particles and wheat straw's by modified UF resin. In order to making good quality flax particleboard, the tow and sand existing in flax should be discarded by shifting and screening, or these materials will decline the properties of flaxboard. Much research work has to be done for further development of using non-wood fibrous raw materials. For example , the thickness swell of particleboard made from millet straw should be further improved and density and resin content in manufacturing particleboard made from bamboo may be reduced.

According to characteristics of non-wood fibrous raw materials and problems appeared in research and experiments at CRIWI, it is necessary to further develop and improve suitable technology , equipment and special adhesives, so that the non-wood fibrous raw material composite products can be successfully developed in China and play a more important part in saving wood resources, while providing more composite products supply and promoting China's economics.

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RECONSTITUTED WOOD PRODUCTS:
PAST, PRESENT, AND FUTURE

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ABSTRACT

The past, present, and future of wood-based composite materials are discussed. A historical examination of market share by various building and industrial wood-based products shows intense and dynamic competition between competing materials and dramatic shifts in market share in response to the introduction of new technologies. Product innovations, processing innovations, and significant competing material innovations are reviewed, and eight likely future changes in the wood composites industry are discussed. Market opportunities, future product possibilities, and marketing trends are reviewed in light of the flexibility that making products using composite technology provides.

INTRODUCTION

Materials technology researchers are showing increased interest in the benefits that composite technology can bring. In a broad sense, a composite can be defined as any combination of two or more materials, in any form, and for any use. In the wood industry, the terms composite and reconstituted are usually used to describe any wood product that is "glued" together. The product range in the wood industry can be from fiberboard to laminated beams and components. Whatever definition is used, the objective of composite development is to produce a product whose performance characteristics combine the beneficial aspects of each constituent component.

The opportunities that wood-based composites offer in terms of optimized performance, minimized weight and volume, cost effectiveness, fatigue and chemical resistance, and controlled biodegradability, among many other advantages, are available to virtually every products producer. The materials available to form composites are not limited to just wood constituents.

Structural panels (which include plywood, oriented strandboard (OSB), and waferboard-type products), insulating board, and hardboard have shown steady growth but have lost some market share to competing products made from steel, aluminum, vinyl, and plastic expanded foams, for example. Similarly, particleboard and hardwood plywood have lost some market shares to competitors in recent years. Unless something is done to improve their competitive performance, opportunity for growth will be limited in the next 20 to 30 years.

The purpose of producing a new composite is either to produce the material more cheaply or to improve its performance (or both, if possible). Composite technology provides the opportunity to produce performance-enhanced composites, which combines two or more materials in such a way that a synergism between the materials results in a composite that has performance attributes that are superior to those of the individual components.

This paper reviews the development of composites from a historical perspective, and it reviews some of the significant innovations and trends that have occurred in the past or that are occurring now. It discusses likely changes that may occur in the composites industry as well as future product and marketing trends for the wood composites industry.

SIGNIFICANT INNOVATIONS AND TRENDS IN THE WOOD COMPOSITES INDUSTRY

Intense competition among various products has long typified the North American materials industries. Although this fact is generally recognized by those working in the materials field, it is worthwhile to occasionally review developments of the recent past as these provide some perspective as to what might be anticipated in the future.

Development of the North American forest products industry has been greatly influenced by the introduction of new processing technologies and new products. Professor James Boyer (1989), University of Minnesota, presented information on this subject at the Society of Wood Science and Technology annual meeting in June 1989. Almost every new technology and product introduced has led either to an increase in the amount of raw material converted to a useful product or to an expansion of the type or form of raw materials that could be used. Table 1 clearly indicates that as new processes and products have been introduced, conversion efficiencies of raw material to useful product have increased markedly.

Table 2 provides a list of some of the significant product innovations that have occurred during the past 50 years. It includes data for vinyl siding and points out that, more and more frequently, raw materials other than wood are being used to produce products that have traditionally been made from wood. Table 2 also indicates that the time span from when a product was first introduced in the marketplace to when the product achieved significant commercial application has decreased significantly in recent years. Table 3 provides information similar to that in Table 2 for selected processing innovations that have occurred during the past 21 years. Table 4 provides information on several significant product innovations that have been announced or introduced into the market place in recent years. Note that all these innovations compete with the traditional wood product designed to serve the same end use. Questions of critical importance to all vendors of established products are, Which products will lose market share to the new innovations and by how much? These questions are difficult to answer, but a careful assessment of relative advantages accruing to various products can provide valuable clues as to which products are most at risk.

With this discussion as background information and realizing that history clearly shows that competition among different materials is extremely intense and dynamic, the next section discusses a partial list of likely future changes in the wood composites industry. These changes could very well lead to improvements in the competitive position of wood as a material.

LIKELY FUTURE CHANGES IN THE WOOD COMPOSITES INDUSTRY

In each of the following categories, only one or two specific examples of likely future changes are listed. In most instances, many more examples could be cited.

Improvements in Processing Efficiencies

Supplying wood products with consistent, predictable characteristics that provide good performance and reliability are essential for maintaining and improving the competitive position of the forest products industry, both domestically and internationally. Manufacturing products with the quality desired by the consumer at a return on investment favorable to the producer is a key element to remaining competitive.

Differences among wood products are primarily related to differences in species, end-use specifications, and product quality. Lumber manufacturing and drying techniques are essentially the same for construction, industrial, and export products. This is true also of panel manufacture and wood preservation methods. Consequently, manufacturing and quality control developments in the wood industry have a broad impact in many markets.

Product quality is of the utmost concern throughout the entire forest products industry. Improvement and consistency in product quality are needed in solid wood, wood fiber, and composite wood products for the construction and industrial markets. Export markets for wood products are especially sensitive to product quality.

Programs like the Integrated Mill Production and Recovery Options for Value and Efficiency (IMPROVE) system, being developed at the Forest Products Laboratory (FPL), will continue to focus on increasing the recovery and value potential of a mill by improving its manufacturing efficiency. The system consists of eight major analysis programs for log processing, lumber manufacturing, lumber drying, dry end practices, veneer manufacturing, veneer drying, plywood manufacturing, and dry storage and shipping practices. In the near future, the IMPROVE program will be expanded to include manufacturing operations in waferboard mills. Each of the programs consists of several routines that analyze various aspects of a given process. They can be used independently or in series, and the programs have proven to be very beneficial in improving the quality and yield in actual mill trials (Lunstrum 1981).

Increased Use of Composite Lumber

The reconstituted wood industry, which supplies particleboard for furniture core stock, has expanded into the structural panel market. The natural evolution of production of underlayment to mobile home flooring and decking has been followed by the development of flakeboard panels for roofs, walls, and floors of timber-framed houses. Technological improvements in flaking, gluing, pressing, and particle orientation are being directed toward fabrication of composite joists. Reconstituted material is being used commercially as web members in I-joists (McNatt 1980) and flat joists

(McAlister 1984), with either veneer or solid lumber flanges. A reconstituted joist, which is rectangular, uniform in density, and constructed entirely of strands made from waste veneer, has recently been introduced into the marketplace (Parker and Pike 1987).

Structural lumber substitutes are products of high growth and high end value in today's marketplace (Laufenberg 1985). New product development, production facility announcements, and vigorous standardization activity from several sources demonstrate the vitality and potential for continued growth of these composite products, which can be divided into three categories:

1. Laminated Veneer Lumber (LVL), which is made of parallel-laminated veneers bonded with durable adhesives
2. Oriented Strand Lumber (Bucking and Wentworth 1981) or Parallel Strand Lumber (PSL) (O'Halloran and Youngquist 1984), which is made with wood elements that are smaller than veneer sheets, aligned, and bonded with durable adhesives
3. COM-PLY (TM)[1] Lumber, which is made with veneer faces and flake or particle core

The potential for revolutionary change in the forest products industry is great, largely because of composite technology. In the past 50 years, solid-sawn lumber and timber construction have given way to this composite revolution. The introduction of glue-laminated beams in the 1940s represented an early step toward composite wood members. Plywood became a superior replacement for nominal 1-in. lumber for subfloors and for wall and roof sheathing in the 1950s and 1960s.

In the sheathing market, plywood currently has stiff competition from the structural flakeboards. In joist, header, and rafter applications, 2-in. lumber is now subject to being replaced by built-up structural components that use LVL.

Direct replacement of structural components is a simple means of gaining light-frame market penetration, but innovations in processing and design will lead toward development of new structural composite systems and materials based on structural and material optimizations. Some leaders in the composites field have begun development of this next generation of structural composites, and we are certain to see much more activity in this field in the near future.

Continued Improvements in Adhesives

The health of the wood products industry in North America is controlled to a great extent by the rate of housing construction, which is in turn controlled by the health of the economy and by demographics. Within the wood products industry, the greatest use of wood adhesives by far is for manufacturing wood composites (Myers 1988).

What can be said about wood adhesives in the future? New technologies and new products are continually being introduced. In addition, using low-quality forest-derived materials more efficiently and cost-effectively is a possibility. Except for two major uncertainties, expectations are that urea-formaldehyde and phenol-formaldehyde systems will continue to be the dominant wood adhesives in the United States. The two uncertainties are the possibility of much more stringent regulation of formaldehyde-containing products and the possibility of limitations or interruptions in the supply of petrochemicals. One result of these uncertainties is that considerable research has been conducted in the area of developing new wood adhesive systems from renewable resources.

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[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

The wood products industry has a long and successful history of utilizing adhesives based on renewable resources. Their performance was adequate to see the United States through World War II and beyond. But the tremendous postwar expansion in the petrochemical industry provided compounds for synthetic resin adhesives so inexpensively that they steadily displaced natural adhesives. When embargo threatened key petrochemicals in 1973, their availability dropped and prices increased abruptly. Industry reacted with an immediate partial return to adhesives from non-petroleum-based resources such as those based on animal and vegetable proteins and on casein. As the availability of oil improved and prices became more competitive, synthetic resin adhesives again became the industry standard. With over 70 percent of all wood products now bonded, industry is concerned about future sources of adhesives in the event that oil supplies are again disrupted by world events. Strong support exists for research of adhesives based on renewable resources with emphasis on (1) materials that can replace phenol, methanol, urea, or resorcinol-type adhesives; (2) copolymeric adhesives involving synthetic resins and natural polymers; (3) new adhesive mechanisms and substrate treatments; and (4) greater exterior durability for animal and vegetable protein adhesives.

Although research results have indicated that a number of new adhesive systems have promise, their commercial use is currently very limited. One example is the use of isocyanate adhesives. The slow adoption of this material is due to the relatively high cost and to toxicity concerns. This material does have some definite advantages, including rapid cure at moderate temperatures, insensitivity of cure to moderately high moisture, good durability, and the absence of formaldehyde emissions. Another relatively recent innovation is the use of a two-part adhesive system that allows plywood to be bonded at 12 to 13 percent moisture content and higher compared to the previously required moisture content of 3 to 4 percent. The use of foamed adhesives for bonding plywood is also becoming more widely used. It has been found that better control can be maintained of the amounts of adhesive being applied, leading to 20 to 30 percent savings in adhesive use.

Urea-formaldehyde and phenol-formaldehyde are by far the dominant wood adhesives used by virtue of their properties and costs. Because of formaldehyde problems and potential petroleum supply problems, new adhesive systems based on renewable resources are actively being pursued as backup systems if needed. Meanwhile, new technologies and products based on current adhesives are continually being developed and implemented (Lambuth 1989).

Low-Density and High-Strength Panel Products

A steam injection process has been developed (Geimer 1982, 1983) that reduces press times for flakeboard, particleboard, and medium-density fiberboard production. The process begins by coating wood flakes with a resin and forming them into a mat. The mat is then loaded into a press and a burst of saturated steam is injected into it through perforated platens. Within several seconds, the temperature in the board's center rises to approximately 104°C. As the board is compacted, the internal pressure increases, allowing the temperature in the center of the board to rise to between 138°C and 157°C. This high temperature accelerates the resin cure. Several seconds after the end of the steaming period, the temperature falls to about 107°C. The temperature stabilizes at 107°C for the remainder of the press cycle. A computer used to control the steam injection schedule also monitors the rapidly changing press operation. It records time, temperature, and several other variables at 1/2-second intervals.

Tests conducted at the FPL indicate that press time for a 1.27-cm-thick board can be reduced from 4-1/2 min to about 90 seconds. Also, the 45 min needed to conventionally press a 5.1-cm-thick board can be reduced to less than 5 min with steam injection.

The new process uses smaller equipment and less energy than conventional pressing methods. Steam injection also offers the possibility of incorporating additives that increase the durability and fire resistance of the board.

The development of steam-injection pressing and the techniques for understanding the fundamental relations governing the chemistry and physics of resin cure and wood bonding during hot pressing will provide a rational basis for designing improved structural composites with controlled densities and controlled density profiles.

Structural Paper Products

Researchers at the FPL have developed a structural fiber concept called FPL Spaceboard (Setterholm 1985). To make the three-dimensional structural board, fibers are press dried against rubber molds with wafflelike configurations to produce two symetrical halves. An adhesive is then used to bond the two halves, creating numerous small shaped cells in the board's center.

Using this technique, FPL Spaceboard can be made as a laminate or a sandwich, thin enough for strong light-weight corrugated containers or thick enough for wall sections. The result is a fiber composite structural material that is strong in every direction.

Laboratory tests show that FPL Spaceboard is between 30 and 200 percent stronger than conventional corrugated fiberboard. Its strength is due to the special configuration of the core and the superior strength imparted by the press dry method that molds the core and facing together.

With further refinement, FPL Spaceboard can provide the wet strength and dimensional stability necessary to build highly engineered structures, as well as significantly improved fiberboard containers. Its superior performance parameters are

1. improved strength and weight characteristics of press-dried fiber facings;
2. unequaled versatility in mechanical design variables--sheet size, cell size, sandwich thickness, and core density; and
3. adaptability to a wide range of raw materials.

FPL Spaceboard is a concept in structural fiber construction and, as such, its full potential for application and its economic payoff are yet to be determined. Thus far, laboratory scientists have made only a limited number of experimental samples. Because of its many design and processing attributes, however, FPL Spaceboard has good potential for use in commercial and residential construction, mobile homes, recreational vehicles, packaging containers, and wall and ceiling panels.

Improved Surface Treatments

Wood finishing research is stimulated by the lack of detailed knowledge about fundamental chemical and physical factors that affect the performance of exterior finishes on different wood species, on composites, and on new, wood-based products. Many new wood products and relatively untried wood finishes are being introduced in the construction markets, and misinformation abounds. Despite a relatively intensive research effort, many misunderstandings and misconceptions still exist about the proper finish and the best finishing practices for individual wood-based products. There is insufficient comparative information about the performance of finish systems and about finish-substrate interactions. Further complicating the problem is the wide range of new finishing materials being applied to the wide range of new wood-based substrates. Problems with substrate-finish durability sometimes result with these new materials. The increasing use of wood treated with preservative or fire retardant poses special challenges to the use of exterior wood finishes. Finish durability problems may be further compounded by environmental and governmental restrictions on traditional paint and stain systems and by restrictions on paint additives.

The following technical challenges and problems will be significant to the future of finished wood for exterior use.

1. Changing substrates--new wood species will be used and the use of composites and overlays will be increased.
2. Changing finishes--waterborne finishes, finishes with higher solids contents, finishes with low-volatility organic compounds in them, and new multipurpose resins for new finishes will be increased.
3. New chemicals will be used for mildew and mold control.
4. Use of factory finishing will be increased.
5. Government restrictions on many finish components will be increased.
6. Safety and health concerns will be increased.

Continuing research on wood finishing and weathering will focus on demonstrating the wide range of performance that can be found for several wood and wood-based panel products, depending on which pretreatment-primer-finish systems are used. Included in the research will be several new finish materials and new wood composite materials that are being introduced in the commercial market.

Wood Stabilization Technologies

Studies on improving wood properties through chemistry began at the FPL in the late 1930s. They were expanded in 1972 with the advent of new technology, improved analytical instrumentation, and environmental concerns for toxic methods of wood protection. At the present time, a worldwide team of scientists, led by Research Chemist Roger Rowell of the FPL, is studying the chemical modification of wood and reconstituted wood products (Rowell and others 1986).

Rowell and others established that chemical modification of solid wood by epoxidation or acetylation gave greatly improved dimensional stability. The mechanism of improved stability is based on bonding chemicals to the cell wall polymers with resultant bulking of the cell walls. Wood, so modified, swells to near its green dimensions so that little additional swelling occurs when the modified wood gets wet. Wood modified with anhydrides, epoxides, and isocyanates has reduced swelling as much as 65 to 75 percent at bonded chemical weight gains of 20 to 30 percent. Biological resistance to marine organisms, termites, and decay fungi is achieved as well when the bonded chemical is distributed in the polymers that are available.

In tests using southern pines, aspen and Douglas-fir flakes, acetylation reduced liquid water uptake by 50 percent and reduced thickness swelling by 85 percent in flakeboards made from acetylated flakes. Repeated water soaking and ovendrying tests showed that both epoxidation and acetylation decreased both reversible and irreversible (springback) swelling in flakeboard when compared to untreated boards. Springback is caused by the release of residual compressive stresses imparted to reconstituted boards during the pressing process.

The FPL modification methods developed for solid wood can be applied directly to reconstituted wood products with no concerns, because standard operating procedures in the composite panel industry are exactly those procedures required for successful chemical modification. These procedures involve working with dry wood components, spraying adhesives on these components, and using relatively high temperatures and pressures to form the finished product.

Particleboards made from acetylated chips also show greatly improved resistance to tunneling bacteria and brown-, white-, and soft-rot decay fungi as well as decreased hygroscopicity. The greatest potential for chemical modification appears to be in dimensionally stable reconstituted wood products, whose commercial application could be very large. This and other ongoing research brings the FPL scientists together with scientists in other countries, including China, Sweden, Poland, the United Kingdom, Denmark, France, Germany, New Zealand, and Japan, in studies on acetylation and other chemical modification techniques.

Wood-Nonwood Composites

Combining wood with other materials to form new wood-nonwood composites presents many opportunities (Youngquist and Rowell, in press). This is a very active research field with many new ideas being examined. Many species of wood are being combined with other lignocellulosic materials, metals, plastics, glass, and synthetic fibers, and the properties of these new composites are under investigation. These new composites will be introduced in the market as low-cost substitutes for more costly materials or in applications where specific performance attributes are required. Through modification of either the wood or the nonwood part (or both), the new composites can have performance characteristics that are superior to either component alone.

Technological innovation and new product development are vital to maintaining industrial competitiveness and increasing manufacturing process efficiency. This, in turn, leads to economic growth and enhances the wealth of the nation. The forest sector of the economy particularly is impacted by the development of new materials such as plastics, metals, cement products, ceramics, and composite materials, which have displaced or have the potential to displace many wood-based products. Increased process efficiencies in many nonwood industries are made by improvements in process systems and the amenability of metals and plastics to high-speed automated machines. It is important to note that processing concepts can effectively utilize wood in one form or another, and they are very amenable to high-speed processing (Marcin 1988).

One processing option for using wood combined with plastics that is being used relies on extrusion or injection molding technology, where thermoplastic resins are thoroughly mixed with finely ground wood particles or flour. This mixture is then forced out through a die to form a sheet product, which can then be processed in a secondary manufacturing operation into a number of molded or corrugated shaped sections. When preparing fiber-reinforced composites using extrusion techniques, the amount of compounding that takes place prior to product formation must be optimized.

Another processing option involves using a high percentage of natural fibers that are blended with synthetic thermoplastic or thermosetting fibers to form a nonwoven mat, which can be handled in roll form and which leads to automated handling and processing in subsequent operations. This mat can be made from a wide mixture of synthetic and natural fibers to produce products that have properties suitable for a variety of end uses. Subsequent processing options can then be used to fabricate flat sheet or panel products or deep-drawn molded configurations.

Because of the increased processing flexibility inherent in both the extrusion and nonwoven technologies, a host of new natural fiber/synthetic fiber products can be made. These products can be produced in various thicknesses from a thin material of 3 mm to structural panels up to several centimeters thick. A large variety of applications are possible because of the many alternative configurations of the product. Three major classifications of potential products can be defined as packaging products, manufactured products, and corrugated or sandwich-type configurations for floor, wall, and/or roof components.

FUTURE PRODUCT AND MARKETING TRENDS

Market opportunities for new products made from composite materials should be explored systematically using techniques of economic and market research. The ideal combination of technical, economic, and market research results in a fusion or synergism that properly integrates information of both kinds in an interactive relationship to provide a sound basis for research planning and decision making. A wide variety of material configurations and market uses are possible; therefore, the identification of as many considerations about product attributes and market potentials as possible is important. The best place to start is with an examination of existing markets where wood competes with other materials in packaging, manufactured products, and building products.

We often impose unnecessary limitations on our thinking about new products and manufacturing processes, because we think only of high technology, or in some cases, very low technology. In fact, continual incremental improvements in both processes often go together to produce better products more efficiently in terms of product performance and manufacturing cost. In many cases when considering new products, economies of scale limit our thinking about potential applications. However, often when a new product is introduced in a speciality, high-valued market, innovations in processing through the so-called learning curve of manufacturing will reduce unit cost to the point where high-volume markets can be penetrated and significant economies of scale can be achieved.

At a conference titled "Opportunities for Combining Wood with Non-wood Materials," held at the FPL in October 1988, Professor James Utterback, Massachusetts Institute of Technology, spoke on applying new technologies toward the goal of penetrating new markets. In terms of thinking about expanding product lines, Utterback said that introducing new products into new markets is definitely not a good idea. His research has shown that most of the successful companies that have introduced new products into the market place have either introduced new products into markets that they are very familiar with or introduced their existing products into new markets.

History has shown that achieving both market awareness by customers and technological awareness at the same time can be a disastrous strategy for a company. During periods of uncertainty, it is best to broaden the terms of competition with new materials or new markets and deemphasize commodity product emphasis at prices lower than or equal to those of the past, and emphasize substitution, with a sharp focus on factors such as labor saving, reliability, durability, and life-cycle costs.

A company should consider the marketing of specialized products by

1. emphasizing performance,
2. having the performance of a product tailored to the customer needs,
3. having products tailored by the customers themselves,
4. having products at near final shape, so that the customer does not have to do a lot of cutting and fitting, and
5. accommodating the customers' desires to maintain low inventories by making and shipping products based upon customers' needs.

Factors other than meeting customer needs are important when considering new products. Consider why things are done a certain way, and then try to determine other methods to achieve the same end result. Consider whether a product can be made closer to a market, with recycled materials, or with locally available resources.

Professor Utterback made several recommendations for producing new products or entering new markets:

- Go from your technological base to markets that are new to you.
- Do not think in terms of replacement or substitution.
- Stress differences, higher quality, and distinctive features.
- Try to develop performance and life cycle guarantees (for example, against rot or fire). This could lead to new ways of financing or creating mortgages.
- Consider the additions of plastics, foams, and colors that may optimize factors such as energy efficiency or life-cycle costs for windows, siding, and roofing.

- Work with demanding users first, and give them superb technological support. Provide support with standards, test methods, feasibility tests, and specifications.
- Give emphasis to new, smaller firms. Some of them will become the giants of tomorrow.
- Explore widely for concepts that can be modified or adapted to your needs.
- Explicitly examine the thinking behind why things are done the way they are. Are we stuck with only present methods and technology? Can we do new things? Do we need to do all things the same way?
- Combine categories and strategies.

Today we are operating in an environment where customers will increasingly demand uniqueness and individuality in products that they purchase. They will also impose pressures to improve reliability while reducing both cost and delivery times for new products. These intensities will increase dramatically as markets become more international in scope. One way to meet a portion of these demands is through making products from composites that combine the desirable properties of all the materials used to produce the composite.

FINAL COMMENTS

A revolution is currently underway in the structural panel products business with significant changes being made in production of plywood and the development of waferboards, oriented strandboards, and other types of composite panels. Current production trends clearly indicate the increased use of both structural and nonstructural wood-based composite panels for many applications. Structural lumber substitutes, combinations of wood and nonwood materials, and combinations of panels with these substitutes are being made into components and are seen as a growing business that will reach commodity proportions in the near future.

Each material type now on the market was developed to provide properties needed for a specific end use. With time, new uses have continually developed for these materials. The expanded use of these composite materials has resulted in a significant lowering of costs and a greatly improved utilization of the forest resource.

The wood-based panels now on the market are the product of research in all phases of material selection and preparation and in the development of improved adhesives and manufacturing methods. Some key areas where further research could yield substantial benefits include improvements in processing efficiencies, structural lumber substitutes, adhesives for wood composites, low-density and high-strength panel products, structural paper products, improved surface treatments for composites, new wood preservation and stabilization technologies, and wood-nonwood composites.

Intense competition from competing materials will continue in the future. For the full potential of wood-based composite materials to be realized, a number of scientific advances must be made. The combined efforts of university, industry, and government researchers have the potential to provide new developments that will allow the North American wood industry to continue to occupy a leading position in the industrial materials and consumer products picture. These efforts, if focused properly, can lead to the development of thousands of new and useful materials that are unknown today.

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Table 1--Historical perspective of forest products industry technology developoments

	Product volume (ft^3)[a]					
Year	Waste	Lumber	Paper	Plywood	Particle-board	Fuel
1948	14,300	3,600	--	--	--	--
1963	8,700	4,600	3,800	800	--	--
1973	--	5,000	5,900	1,700	1,500	3,800

[a] Assumes that 1 acre of Douglas-fir produced 17,900 ft^3 of logs.

Source: Boyer 1989.

Table 2--Historical perspective of product innovations

Product	Introduced	Significant commercial applications[a]
Hardboard	1926	1955
Particleboard	1955	1973
Waferboard	1958	1983 (5.5 percent)
Hardboard siding	1948	1963 (9 percent), 1973 (20 percent), 1983 (31 percent), 1988 (24 percent)
Vinyl siding	1963	1973 (5 percent), 1983 (12 percent), 1988 (23 percent)
LVL as a structural lumber substitute	1971	1977

[a] Numbers in parentheses indicate the market share of product.

Source: Boyer 1989.

Table 3--Historical persepective of process innovations

Process	Introduced	Significant commercial applications
Chip-N-Saw	1965	1973
Best opening face	1971	1976
Retractable lathe chuck	1965	1973
Centerless lathe	1983	Unknown
Steam injection pressing	1981	1986
Microwave pressing	1979	1986

Source: Boyer 1989.

Table 4--Historical perspective of product innovations

Year	Innovation introduced
1980	All-vinyl windows
1983	Lightweight coated paper Lightweight precast ceramic housing units
1986	Production of corrosion-resistant steel railroad ties Glass fiber reinforced gypsum panel patented Steel frame home boxes
1989	All-plastic house shown at NAHB convention

Source: Boyer 1989.

THE USE OF WOOD FOR ENERGY AND CARBON IN AUSTRALIA: RECENT INDUSTRIAL DEVELOPMENTS

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FDC: 839.81: 867.5: (94)

Summary

A detailed survey conducted on 39 wood based and 18 non wood based companies with wood-fired industrial installations for process heating and electricity generation in Australia showed a total installed thermal capacity of 616 MW. Most of the 88 systems surveyed were installed over the last decade particularly after 1985. Factors responsible for the significant increase are: technological improvements in wood combustion and wood handling, establishment of companies in commercialising appropriate technology, implementation of an unattended solid fuel boiler code, Government assistance and tax incentives for new equipment and successful marketing of wood residues. The survey has found that wood residues are the cheapest fuel at 0.06 ¢/MJ ex mill and 0.34 ¢/MJ delivered over 100 km compared with conventional energy sources.

New applications for wood charcoal as a metallurgical carbon over its traditional use as a fuel is resulting in the large scale production of high quality carbon based on forest residues.

Keywords: Wood energy survey, wood combustion, charcoal

Introduction

The forests have traditionally been a renewable source of firewood, timber, structural wood and fibre. Taken world-wide, fuel wood and charcoal accounts for the largest single use of the wood production. In Australia, wood fuel has been dwarfed by the fossil fuels: coal, oil and natural gas. However, it is still a viable energy source today and is regarded by many of its users as a cheap, clean-burning fuel, low in ash and with no sulphur.

Over the last five years, in particular, there has been renewed interest in wood residue combustion equipment for process heat applications based on new, automated technology. The industries which use wood fuel generally have a small to medium demand for process heat and are located close to the wood source. In these situations, wood is a highly competitive fuel even compared to coal, particularly in decentralised townships around centres of wood production.

The use of wood fuel for domestic comfort heating is also significant in country areas and has increased in recent years in the temperate capital cities, due to nostalgia and the social warmth of a wood fire coupled with the lower energy costs in cases where it replaces oil or electric heating.

Charcoal production in Australia over the last decade has been confined to a small recreational fuel market. However, because of the high demand for industrial wood carbon, a large wood carbonisation plant has been installed.

Comparative Cost of Wood Residue Fuel with other Energy Sources

Green sawdust is the most commonly available fuel particularly from hardwood sawmills where the sawdust is usually disposed of by incineration or landfill dumping at a significant cost to the industry. At sawmills dressing kiln dried wood, there is an availability of dried shavings, sawdust and dockings. Most hardwood operations producing kiln-dried timber burn only a small portion of their total wood-waste to supply energy for drying. Where green and dry sawdust/shavings are sold as a fuel, it attracts a nominal price at the mill gate. If further processing is required such as hammermilling shavings and dried dockings, or providing storage bin loading facilities, this is added to the cost. A typical price charged for green sawdust

The various energy sources are compared with each other in Table 1 on the basis of the cost in cents for a megajoule (MJ) of the useful process heat produced. This is calculated on the basic fuel cost divided by both the gross calorific value of the fuel and the boiler or heat recovery efficiency which takes into account the unrecovered latent and sensible heat lost in the flue gases (Fung 1988). On this basis, green sawdust is the cheapest fuel at 0.06 ¢/MJ ex mill and 0.2 ¢/MJ delivered over 50 km. Over a longer haulage of 100 km, it costs 0.34 ¢/MJ which is comparable to bituminous steaming coal (0.25–0.36 ¢/MJ) and brown coal fuel (0.36–0.45 ¢/MJ), natural gas (0.44 ¢/MJ) and LPG (0.64–0.85 ¢/MJ).

Dry wood fuel, comprised of hogged wood dockings and shavings at 10–15% MC, is an excellent fuel from one supplier costing 0.19 ¢/MJ while green fuel wood chips at 0.12–0.37 ¢/MJ are also very competitive.

There is a very large price differential between wood fuel costs and industrial diesel fuel at 1.71 ¢/MJ and furnace oil at 1.30 ¢/MJ. Heating with day rate electricity is the most expensive at 3.03 ¢/MJ but is cheaper during off-peak at 0.95 ¢/MJ. For large electricity consumers of over 5MW, it is possible to use the high voltage option costing 1.75 ¢/MJ but the user is required to provide and operate a sub-station transformer.

Table 1: Approximate cost of energy for various fuels.

Fuel	Basis of costing	Calorific value (MJ/tonne)	(%) Heat recovery efficiency	Fuel cost (¢/MJ)
Wood residue	Sawdust (green) ex mill @ $4/t	10 000	65	0.06
	incl 50 km cartage $13/t			0.20
	incl 100 km cartage $100/t			0.34
	Woodchips (green) ex mill @ $8/t	10 000	65	0.12
	incl 50 km cartage @ $16/t			0.25
	incl 100 km cartage @ $24/t			0.37
	Dry hogged fuel 12% MC del $26/t	17 900	75	0.19
Specialised wood-based fuels	Split logs 25% MC @ $90/t	16 000	70	0.80
	Wood briquettes @ $120/t	18 000	75	0.89
	Wood charcoal @ $400/t	30 000	80	1.67
Bituminous steaming coal	5% MC, 15% ash 0.4% S incl 100 km cartage $40–58/t $40–58/t	21 700	75*	0.25–0.35
Brown coal	153% MC, 7.4% ash 1.5% S incl 40 km cartage @ $20–25/t	10 200	55	0.36–0.45
Brown coal briquettes	15% MC, 1.8% ash 0.3% S @ $56/t	22 440	75	0.33
Industrial diesel fuel	@ $585/t	45 500	75	1.71
Furnace fuel	3% S @ $420/t	42 900	75	1.30
Liquefied petroleum gas (LPG)	@ $240–320/t	50 200	75	0.64–0.85
Natural gas	Basic tariff 0.334¢ /MJ	53 200	75	0.44
Electricity	Basic tariff 10.35¢ /kWh		95	3.03

Specialised wood fuels aimed mainly at the high value domestic market are: split wood logs at 0.8 ¢/MJ, and extruded wood briquettes at 0.89 ¢/MJ. These fuels are substantially less expensive than oil-based fuels, although barbecue wood charcoal at 1.67 ¢/MJ is only slightly less expensive than industrial diesel fuel at 1.71 ¢/MJ.

It is difficult for wood fuel to compete with cheap natural gas in serviced areas which is convenient to use but in other areas where the population centres are close to the forest industry centres, industrial wood fuel has made strong inroads into the traditional fossil fuel markets. In some instances, not only are sawmill residues used, but forest wastes such as crowns of fallen trees and non-commercial wood are being converted to industrial fuel chips, thereby assisting the clearing of the forest floor of unwanted debris which provides a source of energy for fungi and other pathogens which inhibits healthy regrowth. Provided the nutrient levels are not adversely affected, by perhaps leaving behind the leaves and small twigs, there is a large resource of untapped forest residues available for use as an energy source.

The Industrial Use of Wood Fuel in Australia

A survey on wood energy systems was conducted in 1988 on 57 companies in Australia with wood-fired installations (Fung 1988). Thirty-nine of these were forest-based industries and eighteen were other industries. The total installed capacity of the 88 surveyed installations was 616 megawatts (MW) thermal. Table 2 summarises the industries surveyed and the various installed capacities.

Table 2: Installed capacity of surveyed wood-fired energy systems in Australia

Industries surveyed	No of companies	Installed capacity (MW)
1. WOOD-BASED COMPANIES		
a. Sawmills	26	167
b. Particleboard/Fibreboard	6	179
c. Plywood/Laminated Wood	3	8
d. Pulp and Paper	2	145
e. Combined Sawmill/Plywood	1	17
f. Combined Sawmill/Plywood/Pulp	1	11
TOTAL WOOD-BASED	39	527 MW
2. NON WOOD-BASED COMPANIES		
a. Cannery, Food-processing	3	24
b. Brickworks	3	17
c. Dairy	3	19
d. Abattoirs	3	12
e. Laundries	2	4
f. Horticulture	2	2
g. Coffee	1	9
h. Essential Oils	1	2
TOTAL NON WOOD-BASED	18	89 MW
TOTAL ALL INDUSTRIES	**57**	**616 MW**

Technologies for Conversion of Wood to Energy

In the wood-based industries, there was a large increase in wood-fired energy systems after 1975 when industry looked for alternative to oil firing during the oil crisis. The technology developed at that time in Australia was based on:

1. Improved grate designs for packed-bed systems to eliminate smothering of the fire and hence cleaner burning
2. Vortex combustor designs which produced intense combustion temperatures and short residence times
3. Direct injection of dry sawdust which burn in suspension in brick kilns to replace oil firing.
4. Better monitoring and control of combustion conditions to automate many of the older designs
5. Improved wood fuel feed systems essential for optimum performance of the combustion system.
6. To overcome the need for certificated boiler operators, automated, non-steam process heat systems were developed, such as heat transfer oil, direct firing with combustion gases, and flue gas to air heat exchangers.

With these developments in wood combustion, heat recovery and materials handling technology, almost all the advantages that oil fired equipment offered became available in wood energy systems. The capital cost advantage of oil-fired equipment was offset by the cheaper fuel. For the wood-based industry the fuel had a negative value since the residues had to be disposed of if not utilised. Hence, between 1975–1984, there was rapid conversion in this sector. All new installations during that period accounted for 19 units which represented 28% of the systems surveyed. Conversion by the non-wood sectors of industry was also significant, but there was a wider choice of fuels available. This period saw the introduction of 4 units or 20% of the new wood-energy installations surveyed. For all industries, the number of new installations over the period 1975–1984 were 23 units representing 26% of the total (Table 3).

It was clear quite early in the conversion from oil to wood firing that a major advantage enjoyed in oil-fired boilers was unmanned or limited attendance by certificated personnel. In rural areas of Australia, there was difficulty in employing enough qualified boiler operators whose sole task was to attend to the boilers over the number of shifts required. This was particularly the case for small installations where labour costs would be prohibitive. Although process heat can be derived by alternative methods developed as outlined in 6. above, there were many instances where pressurised steam was required. The breakthrough came with the preparation of a draft Australian Standard for unattended solid fuel boilers in 1981 which was proclaimed in 1983. Boiler technology was then developed to conform to this Standard and wood combustion technology pushed further forward in a second wave of development. By 1985, unattended or limited attendance wood-fired boilers became commercially available in a range of sizes up to 10 MW which suited the small to medium industrial heat applications. The sawmilling industry which required steam for conditioning their timber were quick to use the new boilers with 29% of the installations surveyed occurring over the recent period 1985–1988.

Perhaps the most dramatic change occurred in the non-wood based sector. For many years, sawmills in regional centres have been trying to sell their residues to nearby food processing factories which have a moderate demand for process steam with little success. The new generation boilers have made this possible resulting in 14 units or 70% of installations surveyed in this sector occurring after 1985. The companies taking advantage of cheap sawdust and fuel chips, were: canneries, dairies, abattoirs, horticulture companies, coffee processors and laundries with installed capacities of 2–10 MW. In the period 1985–1988 a total of 29 units or 33% of the new wood-fired energy systems were installed in all industries surveyed (Table 3).

Currently, the most popular wood combustion technology is fluidised bed combustion. The Australian development incorporates the fluidised bed combustor and boiler as one integral packaged unit, the system being first introduced in 1985. This system has since dominated the new installations with 15 operational units. The other 14 new installations are based on traditional sloping and stepped grate designs, underfed stoker and vortex type suspension combustors. Wood gasifiers are being used for heating and low pressure steam production.

The largest boilers surveyed were 31 and 57 MW units installed at pulp and paper mills. These are travelling grate boilers built for firing coal but have been adapted to burn 50–75% mixtures of fuel chips and sawdust with coal. This has resulted in savings in energy costs and reductions in maintenance due to the low ash content in wood. The coal available in that area is difficult to mine and contains a very high ash, typically 30%.

There has been no advancement in electricity generation from wood over the last two decades. There are five installations in operation with capacities ranging from 0.2–10 MW electrical output. The lack of incentive is due to the electrification of most industrialised areas in Australia and new, small scale steam driven systems are generally too expensive to purchase and operate. Diesel generators are often used in the very remote areas. Although wood gasifiers running internal combustion engines were developed and promoted in the mid-70s, they were not practical for the Australian scene due to the high operational and maintenance demands. Today, because of the high cost of building large coal-fired power stations to supply an increasing demand for electricity and the environmental impact caused from heat, coal mining and potential carbon dioxide pollution with the greenhouse debate, public generating utilities have shifted their stance on private power generation. They have adjusted electricity tariffs so as not to actively discourage the use of standby power and provide equitable returns on excess power fed into the electricity grid from privately generated electricity. Residue based fuels

Table 3: Year, type and capacity of wood energy systems currently installed.

Year	No of units	Combustor type, size (MW), no. off & heat recovery system used	Installed cap. (MW)
Unknown	15	GQ:4.6,4.9,5,6.7x2,6.8,7,7.1,7.5,7.9,11.3; EO:1.3; EO:1.3; EX:0.1; BS:0.3; AS:4.9	82.1
1926	4	AS:2.9x4	11.6
1940	1	BS:5	5
1950	1	BS:2.2	2.2
1958	2	AS:16x2	32
1959	3	CS:1.5; AS:2.9x2	7.3
1960	1	AW:3	3
1961	1	AS:14.2	14.2
1967	3	DW:11; GQ:8.3x2	27.6
1970	1	AS:4.3	4.3
1972	2	BS:2.2; AS:7	9.2
1973	1	AS:7	7
1975	2	GO:5; GS:2.9	7.9
1977	1	BO:2.9	2.9
1978	2	BO:3.5; AS:11	14.5
1979	1	EO:29	29
1980	3	AX:0.1; HQ:4.4,6	10.5
1981	4	DS:2.9; EQ:8; EO:4.7; HQ:6.6	22.2
1982	6	ES:5; FS:31,57x2; GO:7.5; CO:8	165.5
1983	3	CQ:7.2; CS:1.5; ES:2	10.7
1984	2	BO:0.9,1.4	2.3
1985	5	JS:6.5; BO:4.4x3; ES:0.3	20
1986	12	JS:2,3.5,4x2,6; JO:10; GO:2.2,5.9,7.9; ES:0.3; CS:9; BX:0.9	55.7
1987	7	JS:2x2,5; IS:2; EW:2; CS:10; AS:10;	33
1988	5	JS:6x3,8,10	36
	88		615.7

NOMENCLATURE

COMBUSTOR TYPE
A: Packed bed, flat grate
B: Packed bed, step grate
C: Packed bed, sloping grate
D: Packed bed, spreader stoker
E: Packed bed, underbed stoker
F: Packed bed, travelling grate
G: Suspension cyclonic burning
H: Suspension injection burning

COMBUSTOR TYPE
I: Packed bed gasifier
J: Fluidised bed

HEAT RECOVERY SYSTEM
S: Steam
W: Hot water
Q: Flue gas
X: Flue gas to air heat exchange
O: Hot oil

Wood as a Carbon Source

Australia currently produces charcoal for a barbecue market based predominantly on forest wastes from *Eucalyptus camaldulensis* logging operations and, to a lesser extent, on other hardwood species such as *E. dumosa* from land clearing operations. Batch carbonisation kilns are used exclusively and production is seasonal due to the nature of the market and the flooding of the resource areas during the winter months.

Wood is a source of high grade carbon for metallurgical use due to wood carbon having a considerably lower ash content in comparison to coke. Sulphur and phosphorus levels are particularly low. These impurities cause embrittlement in many ferrous operations. Australia supported a charcoal iron industry from 1948–1981 where pig iron and spheroidal graphite iron was produced from charcoal manufactured from *E. marginata* and *E. redunca* var. *elata*. Two Lambiotte retorts were built in 1958 each with a capacity of 10 000 tonnes per year providing charcoal for the blast furnaces. They were decommissioned in 1981.

At present, there is a demand for high grade carbon for silicon smelting in Australia which is being met by imported petroleum coke and coal based coke at two smelters. The silicon industry however, prefers wood carbon which produces a higher grade silicon metal product at lower cost. To produce suitable wood carbon, two new Lambiotte type retorts have been constructed with an annual capacity each of 12 000 tonnes per year of charcoal. Built at a cost of $7.5 million, the retorts will carbonise *E. marginata* billets to charcoal with fixed carbon contents in the range 90–94%. The wood will be derived from forest residues, thinning, defective and over-mature logs. The charcoal will be used in the adjacent silicon plant, the third in Australia, with a production of 12 000 tonnes of silicon metal per year. The other two silicon producers do not have access to wood carbon and are currently using coal based coke to manufacture lower grade ferrosilicon in one plant while the other produces silicon metal using imported petroleum coke.

The Impact of Utilising Wood Residues for Energy and Chemicals

The increase in the number of wood-fired installations and the use of wood as an industrial fuel during this decade and particularly over the last five years has been significant. This has eased the disposal cost burden of many sawmills near cities and regional centres. Some factors contributing to the success have been the following:

1. Technology improvements in wood-fired combustion systems with automated or semi-automated operation reducing labour andmaintenance costs, improved combustion efficiency and acceptable emission levels
2. Drafting and implementation of the Australian Standard AS2593–1983 code for unattended boilers
3. Efforts by the timber industry to market their residues as a clean-burning, low-cost fuel
4. Companies realising the market need, were established to develop, market, build, supply, install and maintain the wood-fired equipment
5. Government incentives for the installation of new, locally developed technology and conversion of oil-fired equipment by way of tax allowances on the Federal level and technical and research assistance to industries involved in the conversion at both the Federal and State levels.

The production of industrial carbon from wood residues is set to rise as wood carbon finds more uses. New carbonisation technology is becoming available in Australia to help utilise the still extensive untapped wood residue resource.

Conclusions

Wood residues are a highly competitive energy source particularly in regional centres. There is scope to increase its usage for both fuel and chemicals since it would improve the current inefficient utilisation of the forest resource and reduce energy costs to industry.

Wood energy harnessed in appropriate systems is non-polluting and safe. Because it is a renewable resource, it will not interfere with our local and global environment in both the short- and long-term, if properly managed in a sustainable way. The use of wood energy can help Australia and other countries with an unutilised wood residue resource meet its carbon dioxide reduction targets for the year 2010.

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THE PROFITABLE UTILISATION OF TIMBER RESIDUES FOR ENERGY

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SUMMARY

Population growths are placing greater demands on shrinking timber resources. In order to improve the balance between supply and demand in Southern Africa certain well planned nationwide actions have become imperative.

Current programmes involve the doubling of present plantations, the creation of large areas of commercial woodlots, the profitable harvesting of invader bush and the introduction of a new generation of combustion equipment.

The planned equipment will include domestic stoves and industrial combustors which are thermally efficient, fuel saving, clean burning and capable of burning a wide range of fuel types.

Keywords: Biomass, Combustion, Energy, Residues, Timber

INTRODUCTION

Southern Africa is in the unenviable position, in spite of remarkable foresight and admirable undertakings by its pioneers, of once again facing a severe shortage of timber and other biomass residues.

At this time, ambitious plans for creating extensive new plantations and woodlots are being prepared and implemented.

The long term searches for residues by a variety of potential users, have forced the country and in particular the CSIR to consider the best ways of using all available wood resources.

The most effective use of wood residues in the energy field is of special importance. In this report, an attempt is made to indicate why and how combustion equipment with high thermal efficiencies are being developed, for example, by the CSIR.

BACKGROUND

Compared to regions such as North America, the Amazon, Europe and Central Africa, Southern Africa is poorly endowed with natural sources of timber.

About 80 per cent of the trees in South Africa, for example, grow in man made plantations.

These plantations cover a total area of about one million hectare. In contrast to the position about ten years ago, the country is now experiencing a great shortage of wood residues.

Recently commissioned paper pulp and chipboard plants have placed almost insatiable demands on all residues near these plants.

Because the amount of development capital in Southern Africa is limited, the greater part of the planned improvements described in this report, will be self-financed. Each important sector of the overall plan must attract the required entrepreneurs and profit motivated financiers. For example, the team harvesting invader bush, even while operating on a pilot scale, ensure that they do so in a financially rewarding way.

MASS HOUSING

It is estimated that, in order to overcome an existing housing shortfall and to allow for predicted population increases, more than one thousand new homes must be erected every working day.

In their originally erected forms, these homes should have not only one or more bedrooms but should also have at least the following standard equipment: domstic stove, hot water system, kitchen sink, shower and toilet.

Because less than half of the above new homes will have electricity, the minimum quantity of new solid fuel stoves installed per day will be:

50% x 1000 new homes per day = 500 new solid fuel stoves per day

If half of these stoves will burn coal and the other half wood residues, the minimum quantity of new wood burning stoves installed per day will be:

50% x 500 solid fuel stoves per day =
250 wood burning stoves per day

Hence, after 10 years, the additional amount of wood burning stoves will be:

250 new stoves per day x 22 days per month
x 12 months per year x 10 years = 660 000 new stoves

If the above new stoves each burn 0,30 tons of wood fuel per month, then the additional amount of wood fuel required per month will be:

600 new stoves x 0,3 kg wood fuel per stove per month
= 198 000 tons of wood fuel per month

This enormous amount of new wood fuel will become available only as a result of careful planning and adequate preparation.

This evaluation indicates that within ten years the current wood fuel consumption will double from about 200 000 to 400 000 tons per month.

WOOD FUELS

Up to the present, Southern Africa and many other regions have depended on indigenous trees and shrubs for the supply of domestic firewood.

Unfortunately, while populations have increased, indigenous wood resources have drastically declined. Not only have large tracts of local forests been destroyed but their removals have often subjected their exposed sites to extensive top soil erosion preventing any forest regrowth.

It has thus become imperative to replace natural forests with cultivated plantations and village woodlots on an extremely large scale.

FUELWOOD ECONOMICS

Part of the worldwide fuelwood shortage has been the outdated conception that while coal and even charcoal must be paid for, fuelwood is freely available to all.

One of few benefits of the increasingly widespread fuelwood shortage is the emergence of entrepreneurs who collect, distribute and sell this by now scarce commodity. Through this action, two benefits have results:

1. The harvesting of fuelwood has become more controlled.
2) A commercial value of firewood has been established and this value has become market determined like any other freemarket commodity.

Now, for example, firewood, even in remote rural areas, sells at from R50 to R100 per ton.

In cities, supermarkets sell firewood at from R200 to R500 per ton. Because of its enhanced value, there is now an ever increasing commercial interest in planting trees for firewood purposes.

These high fuel costs have persuaded families to become more interested in high efficiency domestic stoves. The following typical thermal effectiveness values will explain why:

Open fires ---- up to 11%
Typical solid fuel domestic stoves --- up to 30%
Modern high efficiency domestic stoves --- 45%

A modern wood stove will use less than a quarter of the traditional open fire.

Sawmillers are beginning to realise that the 60% portion of each tree, which was previously an unwanted and incinerated waste, can now, in the form of fuels, become a much needed positive influence on their cash flows.

PLANTATIONS

It is planned to double the plantation area in Southern Africa from about one to two million hectare.

In the past, the state and mining groups played a leading role in planting trees. Now their roles have been augmented by the large paper pulp and chipboard companies.

More attention is being paid to the recovery and utilization of the so-called forest residues which were previously left behind in the forests.

COMMERCIAL WOODLOTS

An exciting development in Southern Africa will be the introduction of commercial woodlots. An additional one million hectare of woodlots will be created during the next ten years.

These woodlots will provide wood fuels to villagers and provide work for their inhabitants.

It is becoming more obvious to many that woodlots can be profitable, for example, many farmers are planting more trees than ever before. Some have found that tree farming is more rewarding than maize farming, for example.

In its planned form, the typical woodlot will involve many functions and, hence, create many job opportunities for the nearby village dwellers. For example:

a) The planting and harvesting of trees.
b) The manufacture of board (i.e. sawmilling).
c) The manufacture of products from this board.
d) The manufacture of solid fuels from the residues.
e) The distribution of these solid fuels.

For the next three years, at least, the CSIR will play a leading role in the testing and evaluation of existing woodlots and will produce a set of guidelines for the best planning, preparation, care and utilization of woodlots suitable for a variety of localities.

INVADER BUSH

Estimates for the areas of Southern Africa covered by invader bush vary from 20 to 38 million hectare.

In this region, invader bush does not consist of a single species nor the same collection of species. The overall inventory includes many varieties of acacia and non-acacia types, for example.

In general, invader bush includes these trees and shrubs that were not there, in present quantities, say 30 years ago.

The harvesting and utilization of this bush are now under investigation. A current pilot scheme being monitored by the CSIR has involved the harvesting of 2 500 tons of invader bush per month for over 3 years. The scheme employs 360 persons.

The harvested bush, in the form of whole tree chips, can be sold, at a profit, at a rate of R45 per ton.

The following assumptions will be made here in order to estimate the annual amount of invader bush which could be profitably harvested locally:

Area with relatively easily harvestable invader bush = 2 million hectare
Bush density = 15 dry tons per hectare
Regrowth cycle = 10 years

Hence, the annual harvest rate can be:

2 million hectare x 15 dry tons per hectare/10 year cycle
= 3 million dry tons per year

The above quantity, in the form of wood fuel, will be of great benefit to the country.

Farmers who have previously been burdened by an unwanted tree growth may now be faced with the interesting decision whether they should eradicate the invader bush, at a profit, and thereby recover grazing land or whether they should switch to energy farming and harvest the bush on a regular and planned basis.

COMBUSTION EQUIPMENT IN GENERAL

The use of wood residues for energy purposes usually involves combustors in various forms, such as domestic stoves or industrial combustors.

The CSIR felt that a new generation of combustors had become necessary for the following reasons:

1) Combustors should have multi-fuel capabilities:
In other words, they should be able to burn logs, chips, bark, twigs, sawdust, bagasse, etc and even coal without major equipment modifications.

In this way, combustor operators kept their options open and could choose the most appropriate fuel type.

It also meant that the most unwanted wood residues such as bark and sawdust could be reliably burned in relatively simple equipment.

2) Combustors should have high thermal conversion efficiencies:
This implies that for a given quantity of heat the minimum amount of fuel was required.

3) Combustors should cause the minimum atmospheric pollution:
Enviromental issues have become more important and the well known smoke columns issuing from incinerators and some boiler stacks have now become legal transgressions.

4) Combustors should be easy to operate and control:
Equipment that is easy to control should require less expensive control equipment and should be easier to keep at optimum settings.

After years of steady development, the hoped for aims have been fully achieved and a range of commercial units are now ready for the market.

The results have been achieved through improvements in the following fields:

(a) Hang-up free fuel flow arrangements.
(b) Correct primary and secondary air flow distributions.
(c) Easy and convenient ash removals.
(d) Adequate heat insulation.

DOMESTIC STOVES

Bearing in mind the centuries of development behind domestic stoves, it came as a surprise to hear from mass home builders that they could not find the solid fuel stove most suitable for incorporation in their house kits.

They felt that the available stoves had disadvantages such as the following:

a) They were too expensive.
(b) They generated a polluting smoke.
(c) They could not heat domestic water adequately.

The CSIR worked together with a number of stove manufacturers and one or two interesting designs have been developed and are now being marketed.

One set of specific aims, which is of special interest, has been achieve, viz:

1. The installed capital cost of a domestic stove plus water heater is about half that of the eletrical equivalent.
2. The monthly cooking and water heating cost is about half of that of systems using electricity.

INDUSTRIAL COMBUSTORS

Once it embarked on its development of a multi-fuel, high efficiency, low pollution and low cost combustor, the CSIR discovered that a huge market existed for such units. This was demonstrated by a great interest by potential clients. The heating of air and water for various purposes appears to be a major component of industrial activity.

The CSIR is currently conducting a test in which one of these combustors produces the heat necessary to pyrolise wattle logs in order to extract certain chemicals.

It is intended to test the burning of human sewage and rice husks in the near future. Success in these fields will open important new commercial opportunities.

The new combustor has an important application with respect to boilers. Although oil and gas burning boilers are less expensive than coal burning units, Southern Africa uses the latter because of the greater availability of coal and the scarcity of fuel oil and gas.

The new combustor produces a flaming gas similar to an oil or gas burner. Because of this, the new combustor and an oil/gas boiler makes a successful combination with a low overall cost.

DRYING KILNS

The CSIR has a strong relationship with the timber industry. It is thus not surprising that the first practical applications of the new combustors will involve timber during applications.

During this year, both hot air and hot water drying systems will be installed.

In order to achieve the general low cost aims it became necessary to develop the following appropriate technology heat exchangers.

1) Hot gas to kiln air.
2) Hot gas to water.

It is felt that the demand for the above systems will increase while the demand for steam based drying systems will sharply decrease.

Once developed for timber kilns, the same or similar technologies could be used for tobacco drying and the general drying of agricultural products.

Later, special hot air applications such as paint drying, bread baking, etc will be examined.

The following prices give an indication of what has been achieved:

(a) A combustor buring 50 kg of wood fuel per hour and a coupled hot gas to hot water heat exchanger will cost about R26 000.

(b) A range of combustors and associated hot gas to hot air heat exchangers will have the following costs:

50 kg of wood fuel per hour : R 38 000
100 kg of wood fuel per hour : R 62 000
200 kg of wood fuel per hour : R100 000
400 kg of wood fuel per hour : R164 000

FUTURE PLANS

The main aim for the CSIR during 1990 will be to place many domestic stoves and industrial combustors in service as demonstration units in practical conditions.

The CSIR will also develop a new range of solid fuels based on wood residues and harvested invader bush. This development will go hand in hand with special marketing efforts.

It will not be possible to sell some of the planned fuels if the potential buyers have not prepared for their use.

Southern Africa is , for example, not ready yet for the widespread use of whole tree chips as a fuel. However, with the proper preparation and market strategies, it can be confidently expected that whole tree chips can become a popular domestic and industrial fuel.

Some of the new fuels being considered are:

(a) Mini-logs i.e. small diameter short logs.
(b) Semi-compressed whole tree chips.
(c) Blended briquettes or pellets containing mixtures of wood residues and charcoal rich dusts such as coal duff.
(d) Semi-charred wood in various forms.

The CSIR also hopes to make some progress with its intention to make single cell protein and, as a by product, fuel pellets from wood residues.

CONCLUSIONS

Hopefully this report adequately describes the background to the impending and rapid expansion in the availability and utilization of biomass residues.

Also referred to, are a number of ways in which wood residues will be used for energy purposes.

The CSIR is playing a leading role in the following energy related fields:

1) The creation of new wood residue resources.
2) The creation of better domestic and industrial combustion equipment.

3) The development and marketing of existing and new wood based fuels.

This substantial increase in wood energy activities will only be possible if the required planning, financing and implementation program is wisely done and effectively carried out.

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PALM STEM UTILIZATION RESEARCH:
ACHIEVEMENTS AND NEEDS

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Summary

The paper reviews executed and ongoing research on stems of Cocos nucifera,Corypha spp.,Livistona rotundifolia,Elaeis guineensis,Borassus spp.,Oncosperma spp.,Metroxylon spp., Arenga pinnata,and other erect palms.It is recommended that palm stem research should be directed at finding industrial uses for stems from plantation grown palms ,as well as uses for palms growing in areas where conventional timber is scarce. Future research activities for coconut palm stems ,if any, should be concentrated on the economics. Oilpalm stem research should put more weight on non - wood uses. Closer cooperation of wood scientists with researchers from other fields is proposed.

KEYWORDS

Palm stem utilization , palm stem research

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1. INTRODUCTION

The family of palms comprises of about 2500 species divided into 6 subfamilies (Uhl & Dransfield, 1986).Their major distribution is in the tropics and subtropics.Quite a number of palms have been domesticated to provide food, shelter,clothing,hunting and fishing gear and tools.Some became of major importance and were planted in plantations, such as

Cocos nucifera	(Coconut Palm)
Elaeis guineensis	(Oilpalm)
Phoenix dactylifera	(Datepalm)
Borassus flabellifer	(Palmyrah or Toddy palm)
Metroxylon spp.	(Sagopalm)

When the production of the primary produce (e.g.fruits,sap,leaves) declined due to age,or after windbreak,palmstems were traditionally used for construction purposes. With the emergence of large scale, extensive plantations during this century,mainly of coconut - and oilpalm, the need to dispose of large volumes of overaged palm stems arose in order to prevent insects from breeding in them. On the other hand,in many countries where palm stems are in abundance, conventional timber resources are in short supply (e.g. Pacific islands, Sri Lanka, Zanzibar etc.),and palm stem material could fill the gap.

Palm stem research aims at making the two ends meet: the economic disposal of stems from overaged palms and the partial substitution of conventional timbers.Efforts in these are already ongoing for about 20 years.

While research was first focused on coconut palm stems, the scope was widened in recent years to include stems of oilpalm and lately other palms as well.

Projects undertaken by national research institutions in various Third World countries were generously assisted by bi - and multi-lateral Development Agencies. Particular credit goes to the UNDP with FAO and UNIDO contributing considerably to the coconut palm stem research, as well as to the Government of New Zealand;to the Government of Canada ,which is supporting palm stem research for a number of species in the South East Asian region through its Singapore-based IDRC Programme; and to the German Government, which is contributing to this aim through its GTZ - Programmes.

The present paper summarizes the status of research as well as future needs in this field for some erect palms. Climbing palms (Rattan) have not been considered ,since they will be the focus of a separate investigation.

2. RESEARCH AND ACHIEVEMENTS

2.1. Cocos nucifera

Since the coconut palm is the most widely distributed of all palms (over 10 million ha worldwide:Killmann & Wong 1988),most of the palm stem research has been focused on this species and is farthest advanced. Projects undertaken in this field in New Zealand, Fiji, Tonga, but mainly in the Philippines have resulted in more than 560 publications (Killmann,Wong & Khozirah 1989). The subject has been widely covered in research papers as well as in monographs (FAO 1985; Rojo et al.1988) and application manuals (Killmann 1988).

Anatomy, physical and mechanical properties,sawing and machining properties, preservation techniques and methods , and seasoning behaviour have been widely covered for coconut palm stems.Its use for a number of endproducts such as furniture,construction timber, flooring,panelling, pallets and power poles have been established.

Present research under the IDRC sponsored regional Palm Stem Research Project undertaken at the FPRDI, Philippines, focuses on

- availability (Garcia 1989)
- production of cementbonded panels (Tesoro and Pablo 1989)
- improvement of two- man saws for small scale conversion of stems in rural areas (Natividad & Alcachupas 1989)
- search for an effective substitution of Pentachlorophenol (PCP) as fungicide (Palomar 1989)
- transfer of sawmilling and preservation technologies (Eala & Siriban , not yet concluded)

A consortium of German woodprocessing companies intends to import and market coconut palm stem material on the German market.In order to meet the requirements of the German industry, a number of research activities will be undertaken in 1990 under the leadership of the Federal Centre for Research in Forestry and Forest Products, Hamburg.

The Project comprises a compilation of all research results (according to European standards)on properties,woodquality, seasoning and preservation,sawing and woodworking amongst others. Additional research is envisaged on:

- woodworking using CNC tools
- lamination and most appropriate glues
- sanding and lacquering
- extractives
- appropriate woodconnectors
- development of efficient grading system (machinegrading)
- preservation with environmentally acceptable preservatives.

At least in the Philippines coconut palm stem material has found its way into the domestic timber market, where cocolumber is widely sold at half the price of conventional lumber of the white lauan type (Pentacme contorta). Main uses of cocolumber are for construction,as well as wall panelling.This commercialization can be considered to be at least partly a result of the research efforts in this field.

In view of the use of cocolumber for construction,their is still a need to develop standards for this material. This is presently being done by the Construction Industry Authority of the Philippines (CIAP) with the assistance of FPRDI and the Product Standard Agency of the Department of Trade and Industry. A Design Manual is being prepared by FPRDI.

2.2. Corypha spp.

The Corypha palms are widely distributed in the Indo-Malayan archipelago,but occur as well in India and Sri Lanka. Presently they are only found wild. Most important species are Corypha umbraculifera and Corypha elata(Buri).The latter is the third most economically important palm in the Philippines (about 2 million palms;Brown 1951) after Cocos nucifera and Nypa fruticans.

Up to now mainly the fibres of Corypha were used for making hats, cloth and sails (Tobler 1943).Furthermore,the sago of the trunk was extracted, and the palm leaves were used in India for papermaking.Since Corypha is amongst the world's tallest and most massive palms (Whitmore 1979),the trunk might in the long run become a source of timber,or rawmaterial for composite products.Therefore research has been undertaken in the Philippines on

- anatomical,chemical and physical properties (Espiloy et al.1989)
- sawing and machining properties (Mosteiro 1987)
- furniture manufacture (Mosteiro 1987).

The Research is ongoing.

2.3. Livistona rotundifolia

Like Corypha, Livistona species are mainly occurring in the wild in South East Asia and Northern Australia ,but are nevertheless planted as ornamentals. The leaves are used locally for weaving of hats, fans etc.In Australia ,there are reports on the efforts to manage Livistona australis and market its timber for oyster stakes (Bishop 1982).

Research on Livistona rotundifolia has concentrated in the Philippines on

- anatomy, physical,chemical and mechanical properties (Espiloy et al.1989)
- sawing and machining properties (Mosteiro 1987)
- furniture manufacture (Mosteiro 1987).
- treatment of poles (Siriban, not yet concluded)

2.4. Elaeis guineensis

Elaeis guineensis , originating from West Africa,has become a commercially important crop particularly in South East Asia (in Indonesia and Malaysia alone over 3 million ha). Its present economic life ends after 25 - 30 years,when the palm is felled and replanted.In Malaysia alone, Abd. Razak et.al. (in press) estimate 3 million cum of oilpalm stems to be removed in 1990. The amount is calculated to rise up to 19 mio cum annually up to the year 2000.

Presently, the palms are mainly pushed over,chopped into shreds with the help of the bulldozer ,and lateron burnt, The costs per palm rise up to $ US 3.7 per palm or about 380 $US /ha (Killmann and Woon,in press). In order to use this enormous resource, as well as to reduce costs,a number of research projects have been undertaken,mainly at the Forest Research Institute Malaysia. Anatomical features as well as physical, mechanical and chemical properties have been investigated. Sawing and machining properties have been tested,as well as various seasoning and preservation techniques and preservatives.The potential use for pulp and paper as well as for a number of composite products have been analyzed. However, in spite of all the research undertaken, reflected in over 90 publications and papers (Killmann ,Wong & Khozirah 1989) ,no economic use could yet be found.This may be attributed to the fact that the properties of the oilpalm stem are still less favourable than those of coconut palm (Killmann and Wong,1988).

Economic uses of oil palm stem material as timber substitute for conventional uses are presently highly unlikely.However, taking into account some of its properties (high sugar and starch content, high initial moisture content),research for this resource concentrates on :

- conversion into cattle feed
- conversion into liquid fuel
- manufacture of gypsum fibre board.

The research is ongoing. In these fields the Forest Research Institute Malaysia closely cooperates with the Food and Agriculture Organization of the United Nations (FAO),the German Agency for Technical Cooperation (GTZ), the International Development and Research Centre (IDRC,Canada),the Tropical Agricultural Research Committee (TARC,Japan) , and with other Malaysian Research Institutions.

2.5. Borassus spp.

The Borassus palm or palmyrah palm consists of two species: Borassus aethiopium (Africa) and Borassus flabellifer (South- and South East Asia ,Kovoor 1983).The traditional uses are :

- fruits (in Malaysia it is called sea coconut)
- palmsap for "wine"(toddy),"arrack" and jaggery production
- handicrafts from fibres and leaves (Maydell and Erichsen 1968).

Cases of use of the stems for construction purposes in rural areas have been reported from Africa (Gschladt 1972) as well as India (Davis and Johnson 1987).Investigations have been concentrated mainly on palm sap and methods of its extraction.

In order to make better use of overaged Borassus stems in areas where no conventional timbers are available,this resource is presently being investigated at the Kasetsart University, Bangkok, Thailand (Anon 1989). The ongoing research covers the following fields:

- availability
- anatomy
- physical and mechanical properties
- sawing properties
- seasoning behaviour
- natural durability.

2.6 Oncosperma spp.

The species Oncosperma horridum and Oncosperma tigillarium are widely distributed from Ceylon to the Philippines.In Thailand and Malaya,the stems have traditionally been used for rural construction, and in splitform for flooring ,as well as for agricultural tools. Due to its recorded durability in sea water, Oncosperma horridum is much used in marine construction.

In order to get a better insight into possible uses of these palms, researchers at Kasetsart University in Bangkok,Thailand, are presently investigating in the following fields:

- availability
- anatomy
- physical and mechanical properties
- sawing properties
- seasoning behaviour
- natural durability.

2.7. Metroxylon spp.

The sago palms, especially Metroxylon sago and Metroxylon rumphii are distributed throughout South East Asia. The palm stems are traditionally the main source for starch (sago means flour in Malay). Over 120 articles and papers (Killmann ,Wong & Khozirah 1989) have been published on this subject, and three international conferences have been held. However, the starch is only extracted from the central part of the stem.The hard outer layer remains unused.Research into this material is ongoing at the Gadjah Mada University,Yogyakarta,Indonesia (Prayitno 1989).Particularly, the following aspects are investigated:

- availability
- physical and mechanical properties
- potential uses.

2.8. Arenga pinnata

Arenga pinnata, the sugar palm , can be found throughout tropical Asia. Its vernacular name already indicates its main produce, sugar,converted from the sap. Other traditonal products are starch (sago) from the stem and fibres recovered from the black leafsheaths wrapping around the stem (Nana Supriana 1989).Up to now most of the research has been concentrated on sugartapping.

With the changing food habits and new , less laboursome resources for sugar and starch, other uses of Arenga palms might be considered.For this reason the Forest Products Research and Development Centre at Bogor,Indonesia, is presently investigating on:

- physical and mechanical properties
- chemical composition
- sawing and machining properties
- seasoning behaviour
- natural durability.

2.9. Other palms

Research in other palms has mainly concentrated on traditional products like food,and fibres from palm stems , nuts and leaves. Worth mentioning here are Areca catechu (at least 10 publications, mainly on Betel nut),Bactris gassipaes (over 40 publications, mainly on palm cabbage:Arias & Clement 1982), Nypa fruticans(over 50 publications mainly on sugar and alcohol),Caryota urens (sugar:Dissanayake 1976), Orbignya spp. (nuts),andPhoenix spp. (on the stem properties: Rogers, Boyette & Moore 1982).

3. OUTLOOK AND RECOMMENDATIONS

As a result of the research undertaken so far, the following conclusions can be drawn:

- coconut palm stem material succeeded in substituting conventional lumber on some low economy, domestic markets,
- in the first place, palm stems are still a source of non - timber endproducts,
- palm stem material in general failed to substitute conventional timber on an industrial level.

Reasons for this are:

Properties are less favourable compared with conventional hard - and softwoods.Together with low recovery rates the unfavourable properties raise costs for competitive endproducts of quality.

However, we should always bear in mind that timber is not the enduse palms are grown for.It can only be a by-product becoming available on replacement of the overaged palms.

When assessing uses and research needs for palm stems , the priorities have to be set in order not to squander research resources.

There are two options to look at :

- from the supply side, and
- from the market side.

Supply:

We can distinguish palms which are grown in extensive plantations, and palms which grow either wild or are planted in small numbers in villages for subsistence. The first category is mainly made up of:

Borassus spp.
Cocos nucifera
Elaeis guineensis
Metroxylon spp.
Phoenix dactylifera.

All other palms belong to the second category.

Research needs differ considerably for the two. For plantation crops an economic utilization is paramount, because the old palm stems pose a health hazard to the plantations.Since they become available in great bulk at regular times, an industrial use has to be found.

Palms grown by rural populations in Third World countries,or those found in the wild, on the other hand,are only available at irregular intervals and usually only in small numbers.Their stems are available when disease has struck, after storm damage,or in exceptional cases, when they are felled by the owner.From experience, village folk in the different countries try to keep palms even beyond their economic life: they consider it better to continue harvesting even a little sap or a few nuts rather than removing the palm, replanting it and having to wait further 6 years and longer until the new plant is productive.

Rural populations as well as forest dwellers have lived with the palms for endless generations.Usually the palms and their products are tightly knit into their culture ,the people know from experience , which part of the palm is good for what. A survey of the existing literature has shown that for most of the palms not grown in plantations researchers hardly come up with new ideas but rather give a descriptive account of what is done by the respective local population.

Market:

We can look from two sides at the market possibilities of palm stem material

- product oriented
- region oriented.

From the product oriented side we know - as a result of palm stem research so far- that palm stem material can be used as a substitute in many wood and woodbased products. However, where quality and economics of the endproduct are concerned, it can in most cases not compete with conventional wood (the exception is cocowood,e.g. on the domestic Philippine market).

On the other hand, their may be very specific enduses where stem material from some palms could play a role.In times of increasing environmental concern not only the direct product costs but as well the environmental costs incurred by its later removal have to be taken into account. Additionally, Wood Scientists have to accept that there may be other, more economic uses than woodsubstitutes for palm stems. Examples are the potential use of Mauritia flexuosa material as substitute for styrofoam packing material in the Manaus area (Brazil), or the potential conversion of Elaeis guineensis material into cattlefeed.

If we look at the material in view of its regional distribution,the situation changes.There are regions , were the supply of conventional timber is so limited or costly that the use of palm stem material becomes economically viable. Examples are Zanzibar, Sri Lanka, and some Pacific

Islands for Cocos nucifera, East Africa and the Sahel area for Hyphaene thebaica(Doumpalm),and Borassus aethiopium, (Palmyrah palm) and North Africa and Middle East for Phoenix dactylifera(Datepalm).

RECOMMENDATIONS

We have to distinguish between basic and applied research.While basic research will be continued by scientists interested in the matter in order to fill scientific voids, applied research should be concentrated on

- species which are of relevance from the supplyside (e.g.Borassus spp.,Phoenix spp.)
- species which may be of interest on certain domestic markets (e.g. Hyphaene spp.)
- economics for Cocos nucifera.A search of available literature shows that all other aspects have been covered, sometimes already in du - or triplicate. Additional research is not pressing. Now the application of research results is required.
- non-wood substituting uses forElaeis guineensis

Furthermore, a closer cooperation with researchers from other fields is required in order to find economic uses for palm stem material.

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EUROPEAN FOREST PRODUCTS MARKETING
BACKGROUND AND CHALLENGES

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SUMMARY

The paper has been written for members of the newly founded IUFRO Project Group P 5.06 "Forest Products Marketing".

It presents quantitative information, examples and comments on forest products, forest owners and forest industry in Europe, based partly on ECE/FAO-studies. Annual production of about 300 Mill. m^3 of industrial roundwood, 90 Mill. m^3 of sawnwood, 32 Mill. m^3 of wood based panels and 60 Mill. m.t. of paper and paperboard are some of the basic figures. But the different regions of Europe must be analized specifically to get a complete and realistic picture.

To give an idea of actual marketing challenges, information is presented and discussed on areas where perceptible changes may affect the European forestry sector: development of roundwood-removals and forest products consumption until 2000, estab-lishment of a fully integrated EEC-market, steps to new economic systems in Eastern Europe, market effects of forest damages, calls of environmentalists to ban imports of tropical timber.

Finally, the viewpoint of a European scientist as to research tasks and international co-operation in the field of forest products marketing is presented.

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Keywords: Europe, forest products, marketing

1. INTRODUCTION

Europe, that are 33 individual states plus part of the USSR and of Turkey. The majority of European states belong to three economic groups (European Economic Community/EEC = 12 member countries, European Free Trade Association/EFTA = 6 member countries, Council for Mutual Economic Aid/COMECON = 6 European member countries). Even though economies and enterprises are run under similar conditions especially in regard to foreign trade within these groups, forests and forest industries show considerable diversity in Europe.

The manifold reality of forestry in Europe alone makes it a difficult task to present an overview of forest products marketing in Europe in a paper limited to a few pages, to analyse the status of marketing practice as well as research activities and needs. To fulfill such a task, expert knowledge from the countries covered would be necessary, as country reports to be summarized are not available.

In face of such limitations, this paper, written to inform members of the new IUFRO-Project Group P 5.06, does not aim at presenting an extensive description of the forest products marketing practice and research in all European countries and the different branches of their forestry industry. Its goals are

- to present basic information on forest products, forest owners and forest industry in Europe,
- to give examples for the manifold conditions, different from country to country, which mark the forestry sector and form the background for forest products marketing,
- to give an overview of some important changes actually affecting forest owners, forest industry and timber trade in Europe, changes which may be understood as challenges for future forest products marketing.

Surely, this outline will be completed through contributions from and discussions with colleagues from other European countries. The author also hopes that the paper may stimulate ideas within the Project Group as to the problems and research topics to be tackled jointly in an active international team.

2. SOME BASIC INFORMATION

2.1 Forest Products

Figures compiled in Table 1 on the base of UN-statistics convey a quantitative frame of the production and foreign trade of selected forest products, comparing Europe to North America (Canada + USA) and the USSR.

Table 1

Production, Imports, and Exports of Forest Products [1)]

	Unit	Europe	USSR	North America
INDUSTR. ROUNDWOOD	Mill. m^3			
Production		301	292	595
Imports		43	..	8
Exports		26	20	29
SAWN SOFTWOOD	Mill. m^3			
Production		70	89	149
Imports		29	..	34
Exports		22	8	47
SAWN HARDWOOD	Mill. m^3			
Production		18	13	20
Imports		7	..	2
Exports		3	..	2
WOOD-BASED PANELS	Mill. m^3			
Production		32	13	41
Imports		12	..	4
Exports		8	1	3
PAPER/PAPERBOARD	Mill. m.t.			
Production		60	10	84
Imports		24	1	12
Exports		27	1	15

1) Figures for 1987; all figures rounded
"Imports" and "Exports" mean total of imports and exports of individual countries, including intra-regional trade

Sources: ECE/FAO, Annual Forest Products Market Review, Timber Bulletin, Volume XLII, No.5, New York, 1989; FAO, Forest Products Yearbook 1987, Rome, 1989

These global figures sum up and at the same time cover up the characteristics of the individual European countries.

There are a few very small countries, like San Marino or Monaco, without any considerable output of forest products. On the other hand, there is a concentration of production and foreign trade of certain wood-based commodities on a few countries, for example (countries mentioned are listed according to their rank):

- 30% of industrial roundwood is harvested in 2 countries (Sweden, Finland) and another 40% in 5 more countries (France, West Germany, Romania, Poland, CSSR)
- more than 50% of sawn softwood is produced in 5 countries (Sweden, Finland, West Germany, France, Austria)
- about 75% of sawn softwood is exported from 3 countries (Sweden, Finland, Austria)
- more than 50% of sawn softwood is imported to 3 countries (UK, Italy, West Germany)
- more than 50% of sawn hardwood is produced in 3 countries (France, Yugoslavia, West Germany)
- 60% of paper and paperboard is produced in 5 countries (West Germany, Finland, Sweden, France, Italy).

Even though a few main exporting countries can be identified (like Sweden and Finland in regard to softwood-based products), the European countries as a whole cannot easily been divided into forest products importers and exporters. Reality is more complex:

Calculated on the base of roundwood equivalents and including finished products, Italy, usually considered to be a "typical importing country" of forest products, is the main EEC-supplier of forest products to West Germany; furniture and wood-based panels are among the commodities supplied. West Germany itself is a net importer of forest products, but at the same time is an important exporting country; its total exports of wood-based products, among which high quality paper-products are main commodities, exceed the volume of domestic roundwood production. Sweden, to give a last example, actually does not fully use the yield of its own forest resources, but buys considerable quantities of roundwood and woodchips in different European countries as well as outside the continent.

Mass commodities like roundwood, sawnwood in the rough, wood based panels, chemical pulp, or newsprint still are the products dominating forest products markets. Trade of mass commodities mainly is through traditional channels; modern technics can help especially to improve communication and logistic.

Looking at forest products in Europe today, hundreds of "modern products" of high standard and finish, with specific technological and aesthetical properties, developed and designed for specific uses and consumers, should not be forgotten: wooden products for concrete shuttering or thermal protection, in-door decoration or do-it-yourself furniture, playgrounds or noise-prevention. There is few quantitative information on such modern forest products, but apparently their market share is increasing. Interest and experience of industry and trade in progressive marketing strategies can be observed just in regard to "modern" forest products, for which specific market segments must be analized and adequate distribution channels be installed.

2.2 Forest owners

According to figures compiled by UN ECE/FAO (1986), 51% of Europe's about 190 Mill. ha of forests are publicly owned, 49% are private forests. There are, however, considerable regional and country to country differences in regard to the ownership pattern. In Nordic countries, the share of private forests is 74%, whereas in Eastern Europe it is less than 10%.

Within the main categories of public and private ownership, the distribution on sub-groups also differs. "Public" includes state owned forests (40% of total European forest area), but also forests of communal authorities or regional governments. The main sub-category of "private" forests are farm forests (37% of total European forest area), but beside these also industry owned forests (of importance mainly in Nordic countries) and other types of private forests exist. More than 6 Mill. forest holdings in Europe are smaller than 10 ha.

There are close connections between ownership structure and market behaviour, depending on the specific objectives of different categories of forest owners and on the conditions under which they manage their stands (e.g. contribution of forest income to total income of the forest owner, relation of harvesting costs to roundwood prices, tax system, existence or not of effective assistance schemes or co-operative marketing organizations or harvesting enterprises). Results of research studies available in some European countries give evidence of the manifold motives which lead forest owners to adopt their marketing strategies (or to abstain from any forest products marketing), sometimes without any economic reason at first glance.

One important factor valid in most of the European countries and for most of the forest owners, which decide on their marketing according to economic considerations, is the unfavourable relationship between roundwood production costs, especially harvesting costs, and roundwood prices. But despite of this fact, forest owners in Europe practise a wide variety of marketing methods even in the same country: Roundwood is sold on the stock and in form of logs, is sold before or after removal, is sold to harvesting and/or timber trade enterprises or directly to industry, is sold with the assistance of forest owners co-operatives or of state forest agencies or directly by the individual forest owners, is sold by private contract or by public sale or by tender, is sold at variable prices or at fixed seasonal prices - to mention only some of the important variations.

Forest owners do not seem to prefer certain marketing strategies now or in future. In West Germany, for example, many forest owners apparently are deteriorating their marketing services in order to reduce harvesting, sorting, measuring expenditures, giving timber trade and industry more radius of action in logging operations and purchase of roundwood. At the same time, a tendency to extend marketing activitiy can be observed in neighbouring France, where roundwood today is mainly sold on the stock. The marketing of products from European forests remains a very individual business.

2.3 Forest Industry

Enterprises of the forest industry are distributed all over Europe. Weighted by production capacity, a concentration of primary forest industries can be registered in Nordic countries and in the EEC. In both regions together, more than 60% of the sawnwood, wood based panels and pulp producing capacity and more than 75% of the paper making capacity was located in the first half of the 80ies according to UN ECE/FAO (1986).

There are only some houndred mills of the wood based panel and the pulp and paper industry. Their production has been concentrated increasingly in larger units. While the production capacity of the particleboard, the fibreboard and the pulp and paper industry expanded, the plywood industry lost market-shares to imports mainly from South East Asia, and the number of plywood mills dropped considerably during the last 20 years.

Other branches of the European forest industry comprise many thousand units, like the sawmilling industry and the wood processing industry and handicraft. The sawmilling industry alone comprises over 40.000 units, but more than 90% of them have an annual output of less than 5000 m^3 sawnwood. The existance of so many small forest holdings, industry and handicraft units makes the timber trade an important factor in the distribution of roundwood, semi-finished and finished wood products in many European countries. The trade also helps to expand the use of timber in the do-it-yourself and similar end-use sectors.

In the sawmilling industry of some European countries, a rapid process of structural change was going on in the 80ies. Capacity increasingly was concentrated on larger mills (but definitions of "large" are still very different in European countries). The introduction of chipper-canter-equipment in numerous softwood sawmills allowed them to accept logs down to 10 cm top diameter. Coniferous roundwood used only as smallwood for pulp or particleboard before the 1970ies can be graded as sawlogs now, changing the roundwood demand structure. Another aspect of the introduction of new sawmilling technics is the increasing supply of wood residues and chips, which widens a source of cheap secondary raw material for the wood based panel and the pulp industry, requires special marketing attention of sawmills, also affects sales and pricing of small roundwood.

3. EXPECTED MEDIUM TERM CHANGES AFFECTING FORESTRY

3.1 Removals and consumption of forest products

Forecasts and scenarios of the medium-term development of the European forestry sector have been presented in the ETTS IV-study (UN ECE/FAO, 1986). Prepared in a period of downward economic trends and based on data mainly from 1979/81, ETTS IV is due for revision today. Principal trends outlined, however, probably have not changed totally. Therefore, the figures compiled in Table 2 still characterize expected quantitative changes of a few main indicators between 1980 and 2000.

Table 2

Outlook for Roundwood Removals and Consumption of Forest Products in Europe to the Year 2000 1)

	Nordic Countr.	EEC(9)	Central Europe	South. Europe	Eastern Europe	**Total Europe**
REMOVALS (Mill. m^3)						
1979/81	104	91	17	60	80	351
2000	+ 16%	+ 19%	+ 26%	+ 34%	+ 8%	+ 18%
SAWNWOOD CONSUMPTION (Mill. m^3)						
1979/81	11	50	5	14	22	102
2000	+ 8%	+ 27%	+ 23%	+ 66%	+ 12%	+ 27%
WOOD BASED PANELS CONSUMPTION (Mill. m^3)						
1979/81	3	21	1	4	7	36
2000	+ 33%	+ 40%	+ 44%	+ 72%	+ 86%	+ 52%
PAPER/PAPERBOARD CONSUMPTION (Mill. m.t.)						
1979/81	3	33	2	5	6	49
2000	+ 69%	+ 60%	+ 48%	+109%	+ 28%	+ 62%

1) %-changes until 2000 calculated as averages between "low" and "high" ECE/FAO-forecasts; all figures rounded; removals include fuelwood; Nordic Countries = Finland, Norway, Sweden; Central Europe = Austria and Switzerland; Eastern Europe = Bulgaria, CSSR, GDR, Hungary, Poland, Romania

Source: UN ECE/FAO ETTS IV, 1986

Forecasts assume an increase of removals between 1980 and 2000 by about 1% annually. The distribution of total removals into logs (46%) and smallwood (54%) will remain constant, like the share of coniferous (65%) and non-coniferous (35%) removals.

The consumption of important forest products (sawnwood, wood based panels, paper and paperboard) in Europe is assumed to increase at considerably higher rates than removals. This offers forest owners the chance to market the additional roundwood produced. Even so, the demand for imported forest products from other continents will grow in Europe.

Despite of the expected continuous development of roundwood supply and the positive basic market prospects, future development will not be without difficulties for forest owners and the marketing of forest products based on homegrown roundwood. Such difficulties might result out of the fact, that additional removals will be unevenly distributed over Europe. Regions of high additional removals and of high increase of consumption will not necessarily coincide. Also, part of additional removals will be from tree species and roundwood qualities not yet well introduced on European markets. Finally, the level of consumption of forest products to be reached in 2000 and later on depends on the ability of enterprises and organizations of the forestry sector to keep forest products technically and economically competitive and to convince consumers to prefer forest products in the different areas of use.

3.2 Integrated EEC-market until 1993

Wood-consumption in the EEC(12)-countries is about 250 Mill. m^3(r)/year. A volume of about 170 Mill. m^3(r)/year of forest products is imported from countries outside the EEC, whereas annual removals in EEC-forests sum up to 120 Mill. m^3. The desire within the European Community to promote the forestry industry is increasing. Agricultural diversification is one of the main motives, limitation of forest products imports another one.

The governments of the EC-member countries have decided to complete the integration of national markets and to establish a fully integrated EEC-market until the begin of 1993. It can be doubted that the aim will fully be attained at this deadline, but far-reaching steps have been taken already or are being prepared. Measures to realize the Single EEC-Market do not directly aim on the forestry sector. But general conditions for forest owners, forest industry and timber trade are being altered perceptibly. Still it is difficult to foresee the kind and extent of such changes, because many details of the harmonization or deregulation of social policy, environmental policy, product standards, taxes, freedom to work and settle everywhere etc. have not yet been fixed. Some of the changes, however, which the EEC-market integration has set off or is going to intensify within the forestry sector, are visible already:

(1) Marketing areas will grow because of falling transport costs after cessation of controls at internal EEC-boarders and as a result of stronger international competition in the carrying business.

(2) Harmonized CEN-standards elaborated by the European Standardization Committee will be introduced as obligatory technical rules for many forest products until 1992. Non-EEC-member-countries with an important forestry sector, like Austria and Sweden, participate in and influence the CEN-standardization. Harmonization of standards will especially affect markets of such forest products which mainly have been produced according to national standards until now, like sawnwood. CEN-Standards probably will support the use of kiln dry and of mechanically stress-graded sawnwood. It may be expected that harmonization of forest products standards will help larger enterprises to expand their sales and to find new market outlets in other European countries; concentration of the forest products industry, especially of the sawmilling industry, will be reinforced.

(3) Investors have begun to re-evaluate forest industry locations within the EEC, considering factors possibly to be changed because of political decisions and other influences connected with the EEC market integration, like labor costs, raw material availability, transport costs, environmental regulations, marketing possibilities. Projects of the pulp and paper industry to expand or install factories in Spain and Portugal can be mentioned as examples.

(4) The decision of the governments of the EEC-member countries to complete the integrated market within only a few years time has released an astonishing amount of entrepreneurial activity and optimism. Astonishing in so far, as already now trade barriers between EEC-countries are very low, numerous regional markets which practically ignore national boarders have developed since years, many of the larger EEC-enterprises dispose of factories or sales organizations in other EEC-countries, duty free exchange of goods between EEC and EFTA is normal practice since years (i.e. forest products from Austria, Finland and Sweden can be imported free of duties into the EEC region). But apparently many entrepeneurs feel sure that there is still an enormous economic potential to be set free on the way to the Single Market and after its installation. Also, there is an pronounced interest of enterprises located outside the EEC to establish subsidiaries or to buy company-interests in the EEC region; so, Scandinavian and North American companies already have effected aquirements in the forestry sector.

3.3 New Economic Systems in Eastern Europe

Since about five years, the USSR and some Eastern European states (Hungary and Poland, probably following CSSR, GDR, Romania) have begun to change their economic systems. Elements of planned economy are being reduced, steps in the direction to market economy are being taken, giving industry and trade enterprises more leeway regarding their production planning, pricing and marketing. In foreign trade, an increasing number of enterprises will be licensed for direct export- and import-business, while established state branch trade organizations are loosing their monopolistic position.

It is still too early for serious statements regarding future effects of the new economic orders on the forestry industry and the forest products trade of Eastern Europe. The transformation from planned economies to systems which include more market economy elements will take time and new structures will definitely be established only after years of experiments and experience. In the forestry sector, economical and technical east-west-co-operation has a long tradition. The different forms of such co-operation - traditional foreign trade mainly in sawn-wood, roundwood, wood based panels and furniture; return business, where deliveries from other countries are 'paid' with wood products like pallets; buy-back-business, where e.g. woodworking-machinery delivered from a machine factory in a western country is 'paid' with wood products manufactured on the new machinery; joint ventures - are to be revised now.

Enterprises of the forestry sector in Eastern Europe have to expand their knowledge and know-how regarding national and foreign markets. They will have more responsibility to produce and distribute goods in accordance with consumer-needs and to use the sales potential abroad. Improvement of forest products marketing will be essential for the forestry industry and organizations in the countries of Eastern Europe which are on the way to new economic systems.

3.4 Market Effects of Forest Damages

Forest damages attributed to air pollution are being registered on large forest areas in Europe since the beginning of the 1980ies. Monitoring and analysis of possible effects on forest products markets is the task of an Expert Team of the ECE/FAO Timber Committee, which meets annually.

According to the Expert Team's reports, there has not been widespread disruption of roundwood markets attributable to the marketing of trees from damaged stands until 1989. Quantitative analysis of such market effects is, however, difficult because of the absence of satisfactory data on sanitation fellings. Figures available for West Germany indicate that removals of trees damaged by air pollution represented less than 5% of total planned removals in average, with considerable differences between forest areas; regular fellings and anticipated compulsory fellings together could be kept at the level of average annual removals. Investigations on the quality of wood from damaged trees taken from forest decline areas proved mechanical wood properties to be unaffected by tree damage.

Forecasts as to the implications of air pollution damage to forests for wood supply in the years to come are not available. Experts discussing possible future impacts of forest damage on timber markets base their considerations on scenarios or models, setting assumptions in regard to the dynamics of forest damages, the impact on increment of forest trees, the cutting behaviour of forest owners and other important factors. Elaboration of such scenarios by scientists, even though looked at sceptically by forest policy decision makers, should be helpful to allow a timely planning of marketing and market policy measures for the case of severe impacts on forest products markets in future.

3.5 Decreasing Imports of Tropical Timber?

Europe is one of the principal import regions for tropical timber. Imports totalled at more than 10 Mill. m^3(r) in 1987, mainly in form of semi-finished products (sawn hardwood, plywood, veneers), but still include a considerable, even though diminishing share of logs (about 3 Mill. m^3), whereas finished products like furniture parts or complete doors are considerably less than 10% of total volume. About 95% of European tropical timber imports go to EEC(12)-countries.

Since the middle of the 1980ies, deforestation and degradation of forest resources in the tropics and their effect on the environment have become a topic of increasing public interest and political action in several European countries, among them main importing countries like Great Britain, the Netherlands and West Germany. Environmentalists, supported by part of the mass media, call politicians, consumers and import trade to stop or to reduce the consumption of tropical timber.

It is not the adequate place here to discuss as to whether a ban of tropical timber imports would contribute to conserve tropical forests. As a matter of fact, parliaments and governments of European countries and responsible bodies of the EEC have not taken steps until now to reduce tropical timber imports. At its 47th Session (October 1989), the Timber Committee of the UN Economic Commission for Europe expressed its conviction, that "any unilateral measure to restrict the import and use of tropical timber would be counter-productive, taking away an important economic incentive for conserving the forest ..."

On the other hand, the campaigns of environmentalists and mass media against tropical timber seem to meet with a certain response from consumers, architects, part of the wood processing industry and handicraft and of the timber trade. In West Germany, numerous municipalities have decided to abstain from tropical timber for their public buildings.

The further development in this field affects the forestry sector of countries in the tropics as well as in Europe. As to how much and which tropical timber will be used in Europe will be influenced by political decisions, but more than in the past also by marketing-strategies. To keep the market share of tropical timber or to substitute forest products made of European wood for tropical timber are the contradictory aims which interested enterprises will try to realize. A useful contribution of scientists might be to show ways how the use of tropical timber harvested in carefully managed forests can be promoted.

4. FOREST PRODUCTS MARKETING RESEARCH

The new IUFRO Project Group will have to delimite research fields within the manifold cosmos of forest products marketing where international co-operation appears promising. Looking from a European viewpoint, considering the facts outlined in this paper and marketing problems identified, the author would like to suggest that Project Group members examine which of the following research areas might be suitable for their joint efforts:

(1) Forest products marketing as research object: definitions and limitations, methods, research aims (How do scientists see themselves and their duties?)

(2) Improvement of the collection, evaluation and dissemination of market, product and process intelligence: market research methods, market-information-systems, data banks, forecasts etc.

(3) Comparative analysis of roundwood marketing as practised in different countries: economic analysis of alternative marketing models, market behaviour and marketing aims of forest owners

(4) Marketing practice of smallscale enterprises of the forest and wood processing industry and handicraft: strong and weak points, specific marketing approaches, co-operative marketing

(5) Development and market introduction of "modern", higher added-value wood-based products

(6) Market effects of forest damages (including sudden damages), means to avoid negative effects on markets

(7) Effects of the EEC-market integration on the forestry sector of EEC-member-countries and non-EEC-countries

(8) Marketing of forest products industry enterprises in Eastern Europe (Can experiences from market economy countries help to develop the forestry sector in Eastern Europe?)

(9) Protection of tropical forest resources **and** use of tropical timber - compatible strategies?

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MARKETING STRATEGIES FOR THE GLOBAL MARKET

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SUMMARY

Two alternative strategies for the export of wood products are international and global marketing. International marketing targets specific market segments with distinctive product lines developed for each segment. Global marketing exports a single standardized product line to all market segments regardless of geographical location. To successfully compete in the increasingly competitive, world marketplace companies and/or industries in producing countries must understand the requirements, benefits and disadvantages of these two dissimilar export approaches. Choosing appropriate export strategies must be based on a multitude of factors categorized by three domains: 1) supply considerations, 2) demand considerations and 3) internal business and/or industry evaluations. Using the analytical model presented can assist a company, industry and/or country in choosing a suitable export strategy, often a critical component of the long term health of a country's forest products industry.

INTRODUCTION

The emergence of new powerful economic centers, such as the Pacific Rim and Europe, in the latter third of the twentieth century has contributed to increasing world demand for many products (Hopper, 1989). Many of these new economic areas lack the raw materials necessary to become self sufficient in wood products resulting in the increasing international trade of wood products (see Figures 1a, 1b and Table 1). Companies or industries producing wood products view this increased trade as opportunities for establishing or expanding export markets to gain benefits such as economies of scale, full utilization of capital intensive resources and market diversification (Sullivan and Bauerschmidt, 1988). However a poorly planned export strategy can lead to both short term and long term financial losses, under-utilized resources and reliance on unstable market demand. To ensure beneficial exporting operations companies and/or countries with trading potential should develop export market strategies based on a careful analysis of supply considerations, demand factors and internal evaluation. Two distinct strategies exist for export: international and global marketing.

This paper defines these two strategies and then examines the requisite skills, required to successfully implement each approach, their advantages and disadvantages. An analytical method to evaluate the appropriate export strategy for a company or country-based industry is then presented. Specific criteria and strategic implications of choosing either approach concludes this examination of marketing strategies for the global market.

Definitions

International Marketing

International marketing is selling a different product line using dissimilar methods for each international market. It is often equated with market segmentation and targeting specific segments. Product lines and sales techniques may be dramatically adjusted based on cultural and/or economic differences, and geographical proximity between market countries (Day, Fox and Huszagh, 1988). For example, the largest financial institution in the world (Nomura Securities Co., Ltd.,) has expanded in world markets through joint ventures with existing regional financial investment houses to facilitate tailoring services to local markets (Schrage, 1989). An example of international marketing of forest products is the North American manufacture of chopsticks or Hemlock baby squares for the Japanese market. Figure 2 illustrates an international marketing approach.

Global Marketing

Global marketing is selling a standardized product line in the same way in all markets (Levitt, 1986). It is often equated to mass marketing of consumer products. For example, the McDonalds food chain sells identical products in the same manner regardless of country. An example of international marketing of forest products is the promotion of platform (2 by 4 construction) techniques for residential construction. This construction technique uses the same building components, in the same method of construction, with minimal modification due to country of operations. Levitt (1986) contended that the driving force behind the globalization of markets is a cultural convergence due to rapid global dissemination of technology. Global marketing (illustrated in Figure 3) contrasts sharply with international marketing.

INTERNATIONAL MARKETING

Requisite Skills

International marketing requires adjustments of product lines and sales methods based on a thorough understanding of the target market. The exporting firm must be knowledgeable of customers' preferences for both tangible and intangible product attributes and end-uses. This knowledge requires specific information concerning service requirements, packaging, distribution and pricing techniques (Artzt, 1989). Exporting firms need to be aware of cultural differences (both obvious and subtle), existing and changing government trade policies, regional or national economic trends and the codes and standards of the importing country. Thus, a firm using international marketing to different country-markets must have the skills necessary to continuously collect and analyze a multitude of information from a variety of sources within several countries. They must be able to synthesize this diverse knowledge into coherent product strategies adapted for each market. Accepting national differences and adapting operations to appeal to these differences requires a high level of managerial competence and a diverse knowledge of a multitude of disciplines (Levitt, 1986).

Advantages

When segmenting the world market into target markets, these segments can be a variety of sizes from portions of a single country to groups of similar countries. Thus, resource requirements are not prohibitively large, if a company or country wishes to target a relatively small regional segment. This allows companies to enter the international arena without the vast resources frequently available only to large companies or intra-industry associations. For example, several small North American lumber producers profited during the recession in the early eighties by directing their production to a targeted Japanese market segment (e.g. Donnell, 1987).

International marketing allows entry into the world market without a long term, costly investment.

Additional advantages include diminished competition and an ability to create and maintain a competitive advantage. Competition is minimized by being the first to better meet the specific needs of a small market segment, since the cost to competitors of capturing a small market from an established supplier often outweighs the reward (Day and Wensley, 1988). Pioneering advantage (a form of competitive advantage) can be established since the first to develop a product line specific to a target market can influence initial customer perceptions and values of product attributes (Carpenter and Nakamoto, 1989).

Disadvantages

The small size of target markets can also create certain disadvantages. Limited demand minimizes production economies of scale and market growth potential. Focussing on several different export markets results in a large array of product specifications which prohibits standardization and leads to diversity in processing, packaging, and distribution. This complexity often leads to the lack of a simple corporate focus and requires a sophisticated organization to insure that financial allocations do not become diffuse and ineffective (Levitt, 1986). Production of many product lines often results in an uncertain and unmanageable manufacturing process (Port, King and Hampton, 1988).

Sizable amounts of information are required about many target markets. This data is not only difficult to collect but also must be kept current. Since complexity breeds error, producing a variety of products for several different segments, each being marketed to in a different manner, greatly increases the possibility of failures.

GLOBAL MARKETING

Requisite Skills

Global marketing dictates the development and corporate commitment to a single product line. It requires a substantial, long-term expenditure of financial resources to develop an appropriate standardized product line, to cultivate world markets, and to rationalize international codes and standards. This long term corporate commitment must be maintained regardless of short term fluctuations in company and/or industry performance necessitating a consistency of objectives, management personnel and resource allocation (Kashani, 1989).

To succeed in global marketing a company must develop an organization with both clear corporate leadership and strong regional involvement. The direction and strategies from the central organization must be unwavering while integrating the advice, knowledge and expertise of regional managers into operational procedures ("Think global, act local"). The dynamic interaction of these dissimilar, yet powerful, organizational sectors is critical to successful global marketing (Kashani, 1989). While the detail of country specific knowledge necessary for international marketing is not essential, sufficient knowledge to understand customer needs is still required.

Advantages

Development of a global standard can create tremendous economies of scale for production, distribution, management, and marketing a product line. Research and development can be more narrowly focussed improving operational benefits from these programs. A global standard promotes simplicity of product lines which translates into efficient, manageable manufacturing, distributing and marketing systems (Port, King and Hampton, 1988). Economic benefits resulting from these efficiencies can reduce the price of the product line to the consumer and discourage competitive products.

Market and profit potential are vast. As more and more countries accept a standardized product line the potential exists for continuous growth of both sales and profits. Therefore, while the investment is high, the potential payoff is extremely attractive.

Disadvantages

The primary disadvantage of global marketing with its standardized product line is the "putting all eggs in one basket syndrome". Should the standardization not be acceptable to most world markets, the industry or company promoting it may not survive. Thus, while the potential rewards are great, the cost of failure is equally great.

Developing a successful standardized product line provides an attractive target for other firms and countries that can produce similar products. An industry can spend considerable time and money in developing a global standard only to have the market dominated by a late entrant who has a cost or technological competitive advantage. Additional competition can come from producers of other materials. For example, should platform construction gain wide acceptance, the promoters of aluminum studs will increase efforts to capture market share from dimensional lumber products. Opening the competitive arena to a global level increases not only potential rewards and risks but also escalates both intra-industry and inter-industry competition.

DEVELOPING APPROPRIATE EXPORT STRATEGIES

Entering the global marketplace for wood products results in considerable benefits and risks. To minimize the risks, entry or expansion should be based on a strategic marketing plan developed for a specific company, producing region or country. Many factors impact the decision of whether to enter the international arena and, if so, which strategy is most suitable. Three domains of analysis which determine the selection of an appropriate export strategy are supply (focussing on forest resources), demand (using environmental scanning) and internal assessment (inclusive of company evaluation and industry structure). A model of export strategy development based on Day's (1981) development of integrated market analysis is shown in Figure 4.

Supply

Raw material supply can greatly expand or limit strategic options for export. Factors such as species composition, age distribution, material characteristics, timber availability due to competitive uses, and timber access, harvesting, and processing costs must be evaluated prior to export strategy decisions. Species variety can limit the types and quantity of products available for export. Present and future material characteristics of wood dictate end product performance, a critical factor in the highly competitive world marketplace. The age distribution of timber resources can not only impact these material characteristics but also determine long term supplies of products. Ineffective assessment of the forest resource can result in the short term development of market demand which cannot be met in the long term, other than by a competitor with a more suitable timber supply. Competing uses for timber resources can limit the volume available and affect species, size and cost of logs for manufacturing. Costs of accessing and harvesting timber, as well as manufacturing (relative to other producing companies or countries) must be known to evaluate competitive cost advantages or disadvantages. Choice of an appropriate export strategy must incorporate the effect of changing timber supplies.

Developing and maintaining a global marketing strategy requires a continuous, long-term supply of species that can produce a relatively homogeneous product and a globally competitive price. With a long term homogeneous timber supply and a global export strategy, harvesting, utilization, production, research and marketing can be focussed and simplified resulting in the development of competitive advantage due to either low cost or expertise as a result of economies of scale. However, if the timber supply is composed of many species with different material characteristics and there exist gaps in age distribution, then an international marketing strategy would be more appropriate. Each species type could be transformed into an appropriate product based on its best performance characteristics and targeted towards a market desirous of these characteristics. While timber supply is a key ingredient in choosing appropriate export strategies, other factors are equally critical.

Demand

Demand considerations constitute a second key domain of analysis required to develop an appropriate export strategy. Environmental scanning and assessment of the world's business and economic climate provides the information necessary for demand analysis. The need to match corporate, industry or national export strategies with global market opportunities requires understanding exogenous issues and trends which can drastically alter the international marketplace. These issues include economic, political and business factors on a national and international scale.

Economic factors include monetary trends in competitor and client countries. Inflation, exchange rates, interest rates, consumer spending, currency stability and monetary policies are but a few of the economic factors that must be considered. End users in targeted countries must have the present and future ability to purchase the producing country's wood products. Political variables that can contribute to the success or failure of an export policy include trade barriers (both tariff and non-tariff), political stability, nationalistic fervor and methods of transfer of political power. All these contribute to market stability, a requirement for an effective export strategy. Analysis of demand characteristic must incorporate a competitor evaluation including wood product competitors (present and potential), producers of products from alternative materials that could substitute for wood products, the goals of competing firms and countries, and the general business climate of both customers and competitors concerning trade, industry subsidies and investment. Developing and implementing an export strategy is a long term procedure. Stability of market countries and transportation corridors are essential to a successful export strategy.

A global environmental scan can help determine which markets have the greatest potential as clients. Markets that do not promise substantial stability are unlikely targets for a global marketing strategy but may be suitable for a short-term international strategy. Alternatively, the large financial and time requirements for global marketing are suitable for markets that exhibit trends towards open trade, economic growth, stable politics and little internal competition. Environmental scanning of both client and competitor countries to analyze demand considerations is a key element in choosing an appropriate export strategy.

Internal

An internal assessment, which includes examining both the industry structure and the strengths and weakness of individual firms or industry segments, is the third critical domain of analysis prior to choosing a suitable export strategy. Industry structure includes factors such as financial health, structural stability, competitive nature and technological position, all of which can affect the appropriateness of an export strategy. The financial health of the industry frequently dictates the availability of the fiscal and human resources necessary to develop, promote and implement a successful export strategy. An unstable industry structure frequently causes participating companies to act in a defensive manner, restricting long term planning and market development, key ingredients of successful exporting operations. The competitive nature within the industry contributes to the degree of intra-industry cooperation. This cooperation is an important consideration since export strategies are often implemented through industry associations (McCann, 1985). The strengths and weaknesses of companies and/or producing regions must be assessed to ensure that the export strategy chosen compliments the industry strengths. Economies of scale and scope are often inversely related; the greater the economies of scope, the less the economies of scale[1]. The producing company or region must assess their relative economies in both areas to help determine an appropriate export strategy.

If the industry is well established and funded with cooperative competitors using technologically advanced methods to attain economies of scale, a global export strategy would be suitable. Large volumes of standardized products could be produced at competitive costs and the industry, as a whole, could provide the long term financial resources necessary to establish global acceptance of a single set of standards. Alternatively, a uncooperative group of small, labour intensive producers with little economies of scale should most likely follow independent international marketing. Each mill could target a specific target market to best use their limited financial resources. However, industry structure alone cannot determine the appropriate export strategy.

Objectives

Company or industry based objectives must be clearly defined prior to choosing an appropriate business strategy and setting an export strategy is no exception. Objectives for a given company and/or industry must be based on an objective self-evaluation of strengths and weakness. Areas that need evaluation include human and financial resources, security of raw material supply, manufacturing, distribution, marketing, organizational and technological expertise. Specific objectives, based on this evaluation, can be set concerning the proportion of production, by time period, that is to be exported. Goals of product type must be set, that is, are products to be semi-manufactured commodities or manufactured finished goods. Is the goal to export logs, cants, dimensional lumber, parts for finished goods or manufactured products? Export product goals can be volume based or value based. Short term objectives must be compatible with more generic long term goals and industry objectives must mesh with national and government goals to ensure a unified approach to trade negotiations. Company, industry and national export objectives form an important domain of interests that contributes to choosing an appropriate export strategy.

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[1] Economies of scale refers to the decrease in the marginal cost of production of a single product with increasing quantities produced. Economies of scope refers to use of manufacturing systems to produce broad lines of customized products.

CONCLUSIONS

As world trade in forest products continues to grow, many companies and countries are encouraged to export increasing amounts of their products. Choosing an appropriate export marketing strategy is essential to successfully compete in the volatile arena of world trade. The risks and potential gains of exporting into the world market are significant and those companies and/or countries who plan their involvement in world trade based on a suitable export strategy increase their chances of success. Participants in the world wood products market need to understand the strategic options of international and global marketing and recognize the requisite skills, advantages, disadvantages and limitations of each option.

An analysis of short and long term raw materials (supply), world markets (demand) and company and/or industry evaluation (internal assessment) must be carried out within the existing and expected competitive environment. Alternative producers of wood products, as well as producers of substitute products must be key considerations during the analysis. Specific goals, consistent implementation and continuous re-evaluation and analysis contribute to success of an appropriate export strategy. Choosing a suitable export strategy based on a discerning analysis of supply considerations, demand factors and internal strengths, weakness and objectives enhance the opportunities for the successful and profitable export of wood products.

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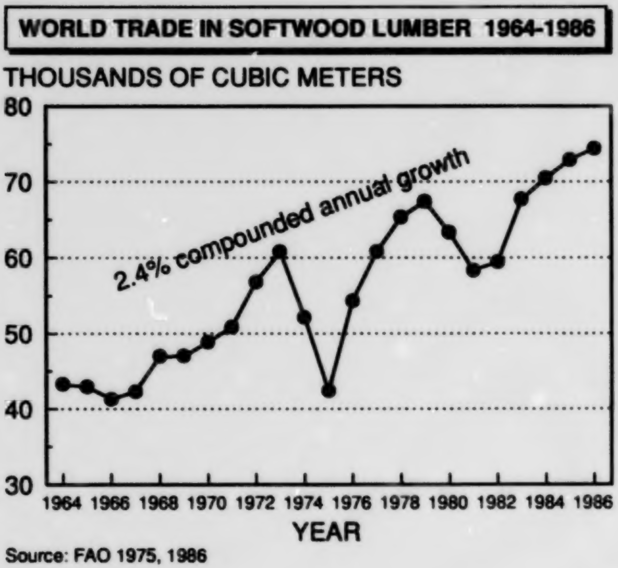
Table 1: World Consumption and Growth Rate by Product Group 1985-2010

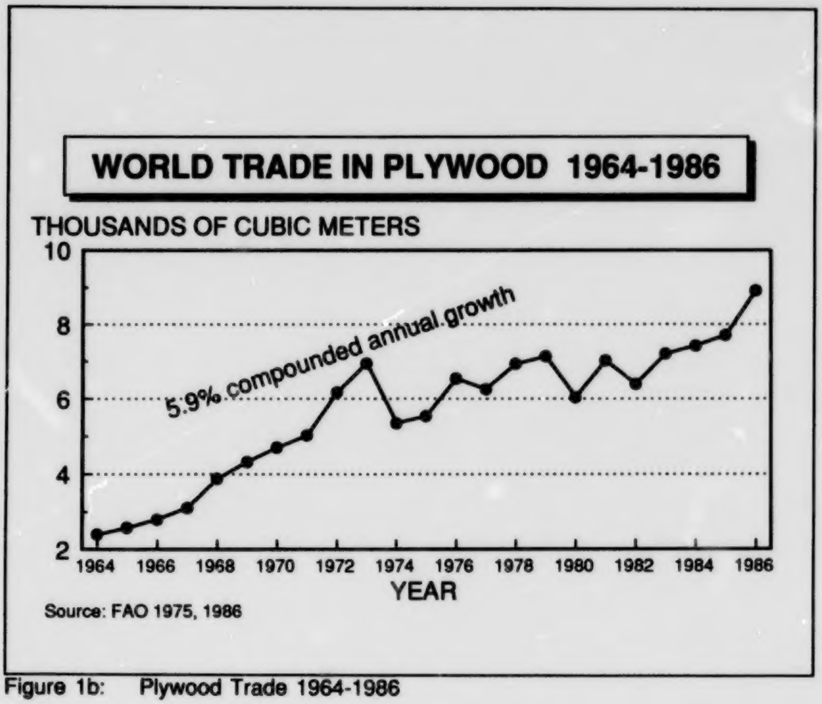
Products	1985	2010	Change	Annual Growth (%)
Paper and Paperboard (in million tonnes)	192.6	342.4	149.8	2.3
Paper Grade Pulp (in million tonnes excluding recycled)	93.2	135.5	42.3	1.5
Lumber (million m^3)	463.0	622.0	159.0	0.9
Structural Panels (million m^3)	109.0	174.0	65.0	1.2

Source: Woodbridge, Reed & Associates, 1988.



Source: FAO 1975, 1986

Figure 1a: Lumber Trade 1964-1986



Source: FAO 1975, 1986

Figure 1b: Plywood Trade 1964-1986

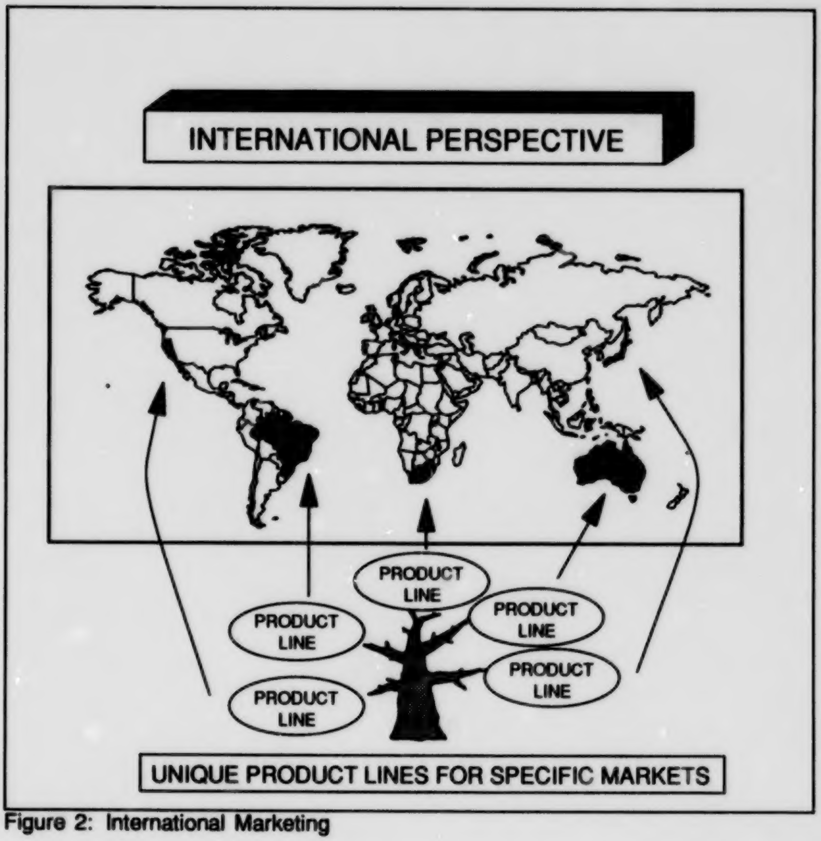

INTERNATIONAL PERSPECTIVE
PRODUCT LINE
PRODUCT LINE
PRODUCT LINE
PRODUCT LINE
PRODUCT LINE
UNIQUE PRODUCT LINES FOR SPECIFIC MARKETS

Figure 2: International Marketing

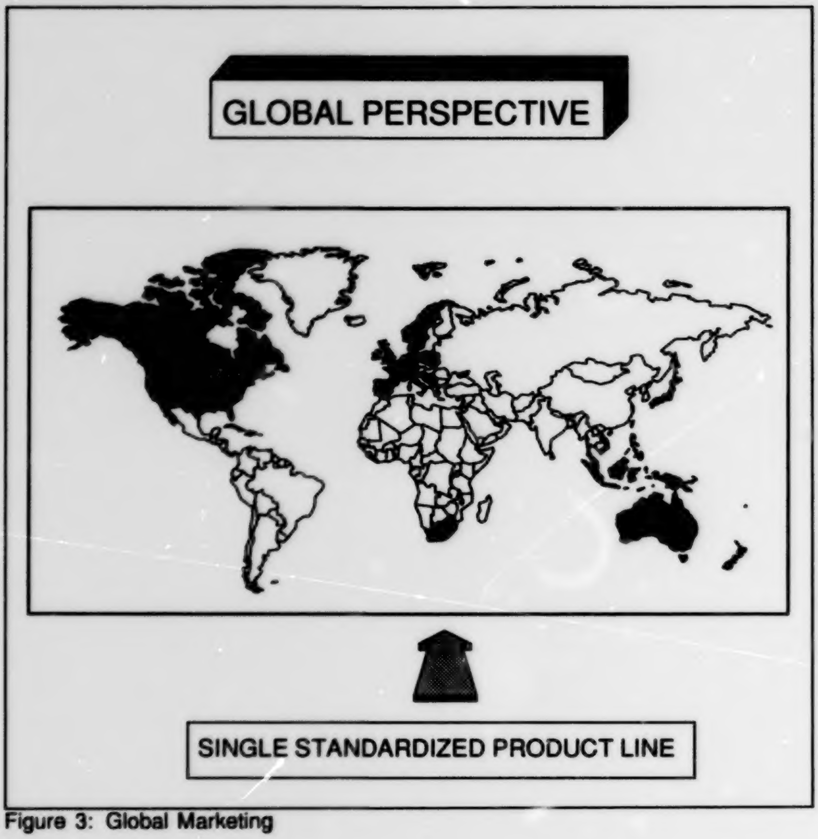

GLOBAL PERSPECTIVE
SINGLE STANDARDIZED PRODUCT LINE

Figure 3: Global Marketing

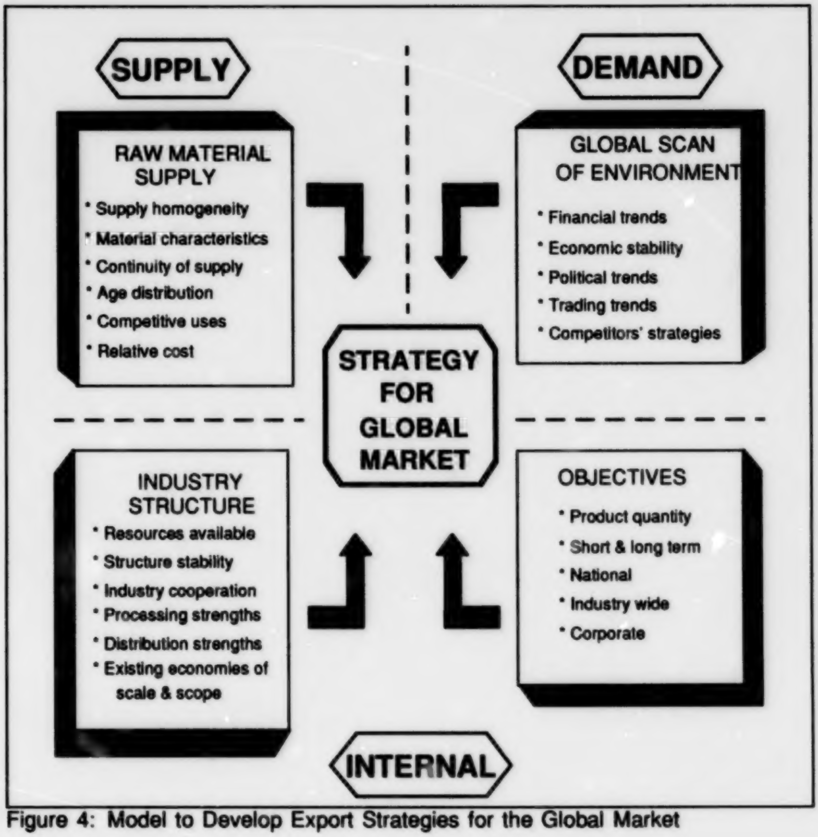

SUPPLY
DEMAND
RAW MATERIAL SUPPLY
* Supply homogeneity
* Material characteristics
* Continuity of supply
* Age distribution
* Competitive uses
* Relative cost
GLOBAL SCAN OF ENVIRONMENT
* Financial trends
* Economic stability
* Political trends
* Trading trends
* Competitors' strategies
STRATEGY FOR GLOBAL MARKET
INDUSTRY STRUCTURE
* Resources available
* Structure stability
* Industry cooperation
* Processing strengths
* Distribution strengths
* Existing economies of scale & scope
OBJECTIVES
* Product quantity
* Short & long term
* National
* Industry wide
* Corporate
INTERNAL

Figure 4: Model to Develop Export Strategies for the Global Market

Voluntary Paper Summaries
Résumés de communications non sollicitées
Zusammenfassungen der unaufgefordert vorgelegten Beiträge
Resúmenes de Ponencias presentadas voluntariamente

Voluntary paper summaries have been arranged in alphabetical order of authors' names.
Les résumés de communications non sollicitées ont été disposés par ordre alphabétique des noms d'auteurs.
Die Zuzammenfassungen der unaufgefordent vorgelegten Beiträge sind in alphabetischer Reihenfolge der Autoren aufgeführt.
Resúmenes de Ponencias presentadas voluntariamente dispuestos por orden alfabético de los nombres de los autores.

COLOR AND GRAIN SORTING FOR FINGERJOINTING CEDAR

T.J. Ar[illegible]

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FDC: 854: 824.6/.7: 174.7 *Cedrus* spp.

Western red cedar grows in many subtle hues and tints of color ranging from pale yellow to a deep brown. The patterns of color which develop are interweaved with vertical and flat grain. To make a uniformly colored, fingerjointed product such as bevel siding from cedar, the chop stock must be graded and sorted by length, color, and grain.

This paper describes an optimizing color and grain scanner which identifies grain and color in cedar at a feed speed of 90 meters per minute. The scanning process combines a fluorescent grade mark reader with a CCD color camera to acquire the locations of defects and evaluate grain and color type. The scanned data is used to optimize the dollar recovery of producing chop stock based on market prices for length, color, and grain combinations.

The scanner technology integrates with existing commercial chop saw/sort lines as an "added value" component of the fingerjointing plant. Color and grain sorting opens the door for marketing aesthetically pleasing fingerjointed products with custom selected colors.

FACTORS AFFECTING THE INTERNAL BOND STRENGTH OF FIBER BUILDING BOARDS - AND ITS RELATION TO TENSILE STRENGTH

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FDC: 862.3: 812.7

For wood based panels the internal bond strength or z-strength is a common routine control. One of the reasons is its correlation with screw holding and fastening properties. For fiber building boards processed wet from a coarse thermo-mechanical pulp this z-strength is primarily a function of board density. At a given density it depends on various manufacturing variables, such as refining, press drying temperature, heat treatment, as well as on binder and wax addition. Such data from experimental work at STFI and from the litterature are summarized. Added are data on the ratio of z- to xy- strength, i.e. the ratio of internal bond strength perpendicular to the board plane to tensile strength in the board plane.

For example, over the density range of 600 to 1 000 kg/m3 using a single pulp the z strength can increase 5 to 10 times. By pulp refining it can be nearly doubled and by heat treatment it can be increased by about 50%. Over this density range the z/xy ratio increases from e.g. 1% at 600 kg/m3 to 4% at 1 000 kg/m3 board density, and more than 6% by heat treatment respectively to 12% by oil tempering. Reorientation of fibers into the z-direction, as achieved by high consistency forming significantly increases the z-strength and the z to xy- strength ratio. The addition of a binder - such as phenolic resin - especially increases the z-strength at lower board densities. At a hardboard density of 1 000 kg/m3 it has an effect only without a heat treatment. The addition of 1% of a cationic wax can reduce the z-strength significantly e.g. to half for hardboard while at lower board density this reduction is less.

For dry process MDF the amount of resin, its relative distribution on fine and coarse fibers and the relative amount of these fractions are of primary importance for the Z-strength.

Results can be explained as combined effect of interfiber bonding area and of bond strength within this bonding area. The results contribute to an understanding of interfiber bonding, especially by covalent bonds.

HIGH DENSITY CORRUGATED WAFERBOARD

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FDC: 862.2

In the past, attention had been given to improvements in specific material properties. Improvement has been attained by optimization of such parameters as density, wafer orientation, wafer geometry, resin selection and content, etc. Little research on corrugated waferboard has been reported. Recently, a press platen system for corrugated waferboard production that can improve bending stiffness approximately 28 times and stiffness approximately 7 times were designed by the Alberta Research Council.

Having achieved the means to improve section properties (beyond flat profiles), we are faced with the task of finding the most economical combination of specific material properties and panel section properties.

As panel flexure performance is the product of "specific materials properties" and "section properties" the density best for flat panels is not necessarily the best for corrugated panels.

In this study corrugated waferboard panels of uniform density ranging from 700 kg/m^3 to 900 kg/m^3 were manufactured. An increase in density of the corrugated panels improves the overall bending stiffness and strength considerably more than comparable flat waferboard.

When equal amounts of wafers are pressed with flat and corrugated platens to form panels of same projected size the results for increased density are as shown in the table below.

Panel Type	Specific Material Properties		Section Properties		Overall Bending Properties	
	E	MOR	I	S	E.I	MOR.S
Flat Wafer-board	up pro-portional w/density	up more than "E"	down	down	down	equal to down
Corru-gated Waferbo	up pro-portional w/density	up more than "E"	down rel. less than flatboard	down rel. less than flatboard	no major change	up

Advantageously, by providing a corrugated waferboard having a higher density it is possible to obtain better wood utilization than in lower density panels. This finding is the opposite to the case for flat waferboard and economic savings to potential waferboard manufacturers could be substantial.

January 11, 1990

ENERGY FROM WOOD - ITS RELATIONSHIP TO GLOBAL WARMING

James S Bethel and W Ramsey Smith

FDC: 831.1: 238: 111.83

Fifteen years ago when the price of petroleum-based fuels suddenly increased in quantum jumps, wood acquired a renewed status as a fuel in the developed countries of the world. Plans were initiated in many of these countries to develop extensive areas of wood fuel plantations. It has never ceased to be the principal fuel in most of the developing countries. In the last decade much of the thrust of forestry development in third world countries has been in the direction of increasing wood fuel supplies. FAO has documented a serious wood fuel shortage in many of these countries.

With the emergence of a major concern on the part of some scientists for what they see as a serious global warming trend fostered by increases in the quantity of the so-called greenhouse gases (primarily CO_2) in the atmosphere. While the principal sources are said to be the combustion of fossil fuels, wood is often treated as a similar source. As a consequence wood as a fuel has increasingly become environmentally suspect. Once viewed as a good substitute for petroleum-based fuel for economic reasons it is now often considered to be a poor substitute for environmental reasons.

What is the role of forests and specifically wood in the global carbon cycle? Is a forest a carbon sink or a source of increased atmospheric CO_2? Will the creation of new forest plantations alleviate the atmospheric CO_2 problem or exacerbate it? Is the impact temporary or permanent? Can the new forest be used? These and other questions are addressed from the vantage point of society's needs for energy and for environmental care.

WOOD QUALITY IMPROVEMENT OF EUCALYPTS IN INDIA

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FDC: 165.3: 851: 861.0: 176.1 Eucalyptus grandis: 176.1
Eucalyptus tereticornis: (540)

Two extensively planted eucalypts in India are *Eucalyptus grandis* and *E.tereticornis*. Recent wood quality studies have indicated that there is scope for the improvement of pulpwood quality of both species. Considerable variation among individual trees was documented in *E.tereticornis* while tree-to-tree variation in wood density was often relatively low in *E.grandis* probably because of genotypic uniformity in South Indian (Coimbatore) seed source.

The wood density or pulp yield increase with age up to 9 years appears to be quite negligible while fibre length and heartwood percentage increase considerably. With an average basic density of 495 kg/m3, the minimum wood density requirement of pulp industry is attained at the age of 3 years in *E.grandis* and there seems to be no significant increase with age as studied in 5-, 7- and 9-year old trees. Fibre length is however about 29% shorter at 3 years than at 9 years (1.15 mm) although the rate of increase declines even before 5-7 years. Almost the same trend in wood property variation has been observed in *E.tereticornis*. The recent research also indicates the opportunity of reducing rotation age below 9 years without significant loss in pulpwood quality if other factors are favourable. Further, the recent finding that wood density is independent of growth rate indicates the scope for enhancing the growth rate of these species with intensive management practices for higher yield.

Work is now under way in Kerala Forest Research Institute on the wood quality improvement of eucalypts selected for disease resistance and higher yield. This includes the estimation of both broad- and narrow- sense heritabilities of desirable wood properties, determination of the effects of provenance and individual tree selection as well as intensive management practices on selected wood properties. International cooperation is desirable at this stage to obtain different provenances for testing. The research findings will hopefully generate necessary information for evolving suitable short rotation management strategies for enhancing the production of pulpwood that has desirable quality.

ASPECTS OF WOOD MACHINING (SAWMILLING) FUTURE

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FDC: 822: 832

Present state of sawmilling in Yugoslavia is characterized by the following main circumstances: many wood species, though fir, beech and oak are most important as sawmill raw material; dispersion of forests and often their mixture of different species; rather low quality and high variety of log diameters.

There are two main sawing technologies; classic technology, producing standardized lumber for the market, and a technology producing parts, mainly for the furniture industry. The latter seems to be prevailing in the future.

The enterprises producing parts operate mostly with single band saws with carriages for log break down. Frame saws are used for the smaller dimensions and the lowest quality logs. Secondary saws, for resawing of boards into parts, are circular and small diameter band saws.

The so-called "flexible saw line" is the latest trend in our sawmilling. It´s characteristics are in the primary sawing (log break down): presorting of logs to the desirable degree; implementation of electronics and computer equipment to get the optimal output from each log (high quality yield as well as high volume recovery); single blade vertical log band saws and band resaws are used for the lumber production; bands must be chosen (tooth patterns etc.) to give optimal cutting (high feed speed, good sawing accuracy, smooth surfaces, high productivity etc.) for either softwood or hardwood sawing.

In secondary processing (resawing, crosscutting etc.): electronic scanning of board forms, sizes and quality; rip sawing with thin multiple saws and single blade circular saws; automatic cross cutting to obtain correct numbers of each specified length of clear wood furniture parts.

MSR LUMBER GRADE RECOVERY FROM INTENSIVELY MANAGED YOUNG-GROWTH DOUGLAS-FIR TREES.

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FDC: 812.7: 815: 238: 174.4 *Pseudotsuga menziesii* Franco

Coast Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) has been one of the most important raw materials resources in the United States during the 20th century. The unique attributes of old-growth Douglas-fir wood have established and maintained the Pacific Northwest as a major factor in domestic and international markets for forest products. The timber resource in the Pacific Northwest is now far along in the transition from unmanaged, old-growth to intensively managed young-growth. Wood from these stands will have characteristics that are different from wood from old-growth, and the way these forests are managed will affect these characteristics. Any of a wide range of possible management regimes can be imposed on these new stands and will impact the characteristics of the wood produced, its value, and its suitability for different products and markets.

The Pacific Northwest Research Station in conjunction with the Stand Management Cooperative have recently completed an extensive study of the product potential of young-growth Douglas-fir. Machine stress rated lumber (MSR) was one of the products evaluated. MSR grading systems have been in existence for 25 years and the production of MSR lumber is increasing as more emphasis is placed on the reliability of wood as an engineering material. Producers of MSR lumber in the Pacific Northwest have little information documenting what the potential yields of MSR lumber will be from the young-growth resource; there is even less information on the impact forest management practices will have on these yields.

The study included logs from over 200 trees selected from 15 different young-growth stands in Washington and Oregon. Study logs were sawn into 2x4's and 2x6's at a conventional sawmill; lumber identity from individual logs was maintained through the sawing, drying, and grading process. Lumber that meet the visual MSR requirements was tested for average and low point modulus of elasticity on a Metri-guard continuous lumber testing machine. Three MSR grades were recognized--2100f 1.8E, 1650f 1.5E, and 1450f 1.3E.

The results clearly demonstrate that yields of MSR lumber can be affected by two key log attributes that are under direct control of forest managers--limb size and the amount of juvenile wood present. Yields in the higher MSR categories dropped off dramatically as limb size and juvenile wood increased. The forestry and forest products communities need this type of information to help set reasonable strategies for growing tomorrows forests.

FACE AND CORE LIGNIN-PHENOLIC ADHESIVES FOR THREE-LAYER WAFERBOARDS

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FDC: 824.832: 862.2

Research and development at Forintek Canada Corp. has demonstrated that lignin phenol-formaldehyde adhesives could be formulated for use as face or core adhesives for three layer waferboards. The ratio of lignin phenol-formaldehyde, catalyst type, pH, spray-drying temperature and lignin cooking base will determine the suitability of the lignin-phenolic resin for a face or core application. Replacement of phenol-formaldehyde with large quality of lignin will require chemical modification of the lignin substrate. Preliminary work on lignin modification using model compounds will be presented.

Machine stress grading of Chilean radiata pine .

Alberto Campos B. Vicente Pérez G. (both of División Industrias, Instituto Forestal, Huérfanos 554, Santiago, Chile). Ying Hei Chui and Ian Smith (both of Wood Science and Technology Centre, University of New Brunswick, Fredericton, New Brunswick, Canada).

FDC: 854.21: 174.4 Pinus radiata D. Don: (83)

Wood, with its inherent variation, has been severely penalized when subjected to the competition of structural materials possessing more uniform mechanical properties. To combat pressures acting against structural use of wood,technologies such as Mechanical Stress Rating (MSR) have been developed. So far the newer technologies have been applied in developed countries such as England, U.S.A. and Canada.

The primary source of sawlogs in Chile is fast grown plantation radiata pine (Pinus radiata D. Don), and lumber products for structural use have traditional been produced ungraded. A project on visual stress grading commenced in 1986 to help improve utilization of structural radiata pine. In order to improve the grading system, and also to bring the Chilean sawmill industry in line with that in other countries,a second project focusing on MSR grading was commenced in 1988. This project focuses on suitable machine settings for Chilean radiata pine.

This paper gives a summary of the advances to date in the Chilean MSR project.

DRY-PROCESS HARDBOARD MADE FROM PRESSURIZED REFINER PROCESSED SOUTHERN YELLOW PINE RESIDUES

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and

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FDC: 862.3: 861.0: 839.83/.84: 812

In recent years wood materials for use by the board industry has become scarce and expensive in many areas as a result of competition with the pulp and paper industry for roundwood and coarse wood residues. Hardboard producers are forced to seek resources that have been previously overlooked and considered undesirable. The U. S. Forest Service reported that large amounts of unused souther pine residues developed from the primary and secondary wood-using industries are available in the southern United States.

It was reported that steam-pressure refining permits the use of southern pine coarse residues in the manufacture of medium-density fiberboard for uses in interior furniture core stock. However, there is a lack of information on the properties of dry-process hardboard made from southern pine residues. Steam-pressure refined southern yellow pine residue fibers were received from a commercial medium-density fiberboard manufacturer. The wood residues were converted to fibrous materials using a defiberator under conditions deemed best for the residue.

The physical and mechanical properties of 3.1 mm thick dry-process hardboards were studied for the effects of resin content, wax content, and fiber treatment. The dependent variables included modulus of rupture, tensile stress, thickness swelling, water absorption, and linear expansion. Both the cold-water soaking and water-boil tests were conducted to determine the potential for use in structural component purposes.

Machine grade yields for structural lumber from fast grown plantation trees. Chui, Y. H. and Smith, I. (Wood Science and Technology Centre, University of New Brunswick, Fredericton, N. B., CANADA.)

FDC: 815: 238: 854.21

The lumber industry in Canada has in recent years begun to produce an increased proportion of lumber from managed forests with fast grown trees. As resources from natural forests become exhausted, this trend will continue and accelerate. Due to the high incidence of growth characteristics such as knots, slope of grain and juvenile wood, the quality of lumber from plantation trees has been observed to be inferior to that of lumber from natural forests.

Machine stress rating (MSR) is regarded as a more efficient means of sorting structural lumber than visual grading. It has acquired increased popularity over the last decade because of the demand for properly sorted materials to be used in highly engineered wood products such as trusses and wood I's. Problems of lumber quality caused by the changing forest resource can be partly compensated for by the use of MSR grading techniques.

A MSR system relies on a representative relationship between strength and stiffness properties of the graded lumber. Research completed at the University of New Brunswick on fast grown plantation white spruce has shown that bending strength of the material is signicantly lower whereas its stiffness property remained virtually the same, compared with values for naturally grown material of the same species.

This paper examines the implication of wood supply related difference in properties on grade yields under a machine controlled system. Comparisons include grade yields of lumber from naturally and plantation grown Eastern Canadian softwood species.

WOOD GASIFICATION FOR HEAT AND POWER - THE PHILIPPINE EXPERIENCE

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FDC: 867.3: (914)

The technology of wood gasification for heat and power in the Philippines will be discussed, starting with research and development activities in 1972 in several institutions in the country (notably the University of the Philippines), the commercialization efforts to propagate wood charcoal gasifiers by the Gasifier and Equipment Manufacturing Corporation (GEMCOR) in 1981, the monitoring of performance of several gasifier-engine systems in actual field operation, commisioned by the World Bank in 1983, culminating with a survey of 64 gasifier installations and interviews with 29 gasifier owners in 1985 to determine the problems and hindrances to widespread use of gasifiers. A number of gas producer systems will be described and operational data presented. Experiences in the marketing of the systems will be recounted and reasons for the failure to propagate the wide use of the technology will be evaluated.

PROPERTIES AND UTILIZATION OF COLIHUE (Chusquea spp) IN CHILE (ABSTRACT)

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FDC: 892.83: 175.2 Chusquea spp.

Colihue (Chusquea spp) grows in Chile and Argentina between 35° and 53° S in association with native forest. It forms erect stems up to 8 m height with about 3 cm diameter and internodal distances of 15 cm. Dense scrubs and thickets are found in the understory of forests of Nothofagus and associated species. It does not require rich soils and is very adaptable to environmental conditions.

Unlike bamboo, the culms are not hollow. On a cross section they show a soft and permeable core surrounded by a hard and impermeable cuticulum. The basic density is 0.36 and the fibre length 1.33 mm. When green, moisture contents average 100 % and the equilibrium moisture content in the Santiago (Chile) region is 11 % in summer and 20 % in winter. Flowering occurs every 15 to 25 years and after fructification, the plant dies. Natural durability is low and the dry stems are susceptible to insect attack. Preservative treatments are advisable.

Colihue may be used for producing chemical pulp of bleachable grades, and paper. Kraft pulp was produced experimentally with different alkali percentages giving a yield of 44.8 to 50 % with Kappa numbers ranging from 8.4 to 15.7. Paper made from this pulp had a tear index of 10.1 mN/g, a burst index of 4.1 kPa.m^2/g and a porosity of 2.5 s/100 cm^3. The strength was comparable to paper from Eucalyptus globulus but inferior to that from radiata pine.

The principal industrial application of colihue is for furniture, similar to rattan from South East Asia. It is particularly suitable for this use because of its high strength for low weight. Prior to colonization it was used by indigenous people for spear shafts and it is now popular for stakes in horticultural plantations and even for markers of slalom runs in skiing competitions.

In Chile, colihue furniture is manufactured in cottage industries but in Argentina there are larger enterprises. Chile exports part of its unprocessed production to Argentina for this purpose. More technology is needed to bring the Chilean industry up to the same level, and greater international cooperation would be useful in this respect.

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TRENDS FOR COMPOSITE MATERIALS IN THE EUROPEAN COMMUNITY

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FDC: 862: 722.1: (4)

At present nearly 17 mio m^3 of wood based materials are produced by the EC countries with a total consumption of 22 mio m^3 in 1985. The net import quota approximates to 4.5 mio m^3. The FR Germany is the biggest producer of particle boards with about 6.5 mio m^3. In the comparatively low European plywood production, France has the leading position with nearly 0.5 mio m^3. The amount of fibre boards produced has been small for years. The highest amount is produced by Spain with nearly 0.4 mio m^3. The European production of wood based materials is characterized in the field of panel boards by: increase of the use of recycling woods; improvement of the top layer and core structures (fine panel board); beginning of the production of OSB. In the plywood field are to be mentioned: reduction of the production of standard veneer boards; increase of the production of technical plywood; increased utilization of small dimensioned peeling wood. No increase in consumption is apparent in the case of hard fibre boards, the consumption of MDF, however, may be expected to exceed the amount of 2 mio m^3.

WOOD STRUCTURE AND NUTRITIONAL FACTORS ASSOCIATED WITH DEFORMATION IN *Pinus radiata* D.Don.

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SUMMARY.

FDC: 811.22: 237.4: 165.3: 174.7 Pinus radiata D. Don

This paper reviews research which has been carried out into the wood structural and nutritional causes of stem deformation in *Pinus radiata* (D.Don) and discusses strategies for future research directions. Copper deficiency symptoms of bent and twisted stems and branches have been found to be associated with low lignification of woody tissues, particularly compression wood. These symptoms can be alleviated through the addition of copper fertiliser.

Visually similar deformation symptoms have been observed in plantations established on fertile ex-pasture sites. These symptoms have been associated with neither low foliar copper levels nor have they been alleviated by the addition of copper fertiliser. Similarly, the deformity has not been associated with low lignification of wood. This phenomenon has been termed the Toorour syndrome. The expression of the syndrome has been confined largely to ex-agricultural soils with a history of fertiliser application and a nitrifying environment, but no other nutritional causes have been identified. The syndrome has a strong genetic base. Research is concentrating on investigating attributes of wood which influence stem rigidity and straightness.

MEDICAL X–RAY SCANNER APPLIED TO WOOD GLUING

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SUMMARY

FDC: 824.8--015.26

The non destructive method of scanner X was calibrated with several species of woods different by their densities. We showed that the real density can also be evaluated in terms of radiologic density (in hounsfield units).

A characteristic of adhesives (gap filling) and joints of gluing of small thickness obtained with european spruce fully and in some cases on partially planed, indicates a gradient of density of adhesives with a maximum value in the center of the joint. The same tendency was approached by FTIR analysis coupled with microscopy. The limits of validity of this analysis was investigated.

NEW EXPANDING GLUE SAVES MONEY

Dr Gérard ELBEZ
(CTBA–PARIS–FRANCE)

SUMMARY

FDC: 824.8

Nowadays glued lamined timbers are more and more used and processes of manufacturing are well known. Any improvements of their properties and conditions of manufacture which reduce cost are valuable in order to compete with no timber materials.

A new process of gluing based on an expanding glue was elaborated by the CTBA.

It can be used to manufacture straight or curved beams with a cost saving about 8% in comparison with traditional glues.

A STUDY OF WOOD EMC DISTRIBUTION IN IRAN

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FDC: 812.213: (55)

Because of hygroscopic property of wood, to prevent volumetric changes from zero to 30 percent moisture content (MC) which reduces the quality of wood and its products, and because of extreme climatic variations in Iran, it was necessary to determine equilibrium moisture content (EMC) of different parts of Iran. Therefore, using the past 20 years climatic data including temperature and relative humidity of 47 cities, EMC and its annual fluctuation is determined.

By comparing the annual temperature changes, relative humidity and EMC curves of these cities and statistical analysis five EMC regions were found in Iran, with a average of 7, 9, 11, 13 and 17 percent. The maximum EMC of 17 percent is for southern Caspian Sea region, and the minimum 7 percent is for the eastern and central parts of the country. Thus, the results of this study show that EMC is below or equal to the allowable moisture content needed for wood in use, except the southern Caspian Sea region. So, wood can be air dried to the final MC in these regions. But, in the southern part of Caspian Sea region wood only should be dried artificially.

Because of EMC variation in different parts of Iran, it is necessary to dry wood after converting to lumber to the EMC appropriate for where it is going to be consumed.

SILVICULTURAL REGIMES TO ENHANCE WOOD QUALITY AND ECONOMIC RETURN IN COAST DOUGLAS-FIR

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FDC: 815:62: 854: 174.7 Pseudotsuga menziesii Franco

A recent study of lumber and veneer volume and grade recovery from managed stands of coast Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco var. menziesii) provides the basis to evaluate differences in value resulting from alternative silvicultural regimes. Small differences in volume recovery result from differences in diameter and taper; however, large differences in grade recovery result from differences in the proportion of juvenile wood and limb size.

About 40 percent of Douglas-fir lumber is in the light framing grades that are used primarily in housing. The price of appearance grades as a multiple of the price of light framing has trended strongly upward since 1971. The price of heavy framing and engineered grades as a multiple of the price of light framing has not shown a clear trend, but the proportion of Douglas-fir lumber being produced in these grades has increased from 25 percent to 40 percent. Econometric price projections for the next 50 years show prices for premium grades of Douglas-fir lumber increasing more than prices for lower quality grades. Prices of all grades of veneer have remained remarkably stable and show no upward trends.

Because silvicultural regimes affect product quality, and premiums for quality are increasing, it is important to reflect these factors in deciding what kind of trees to grow. A computer model, TREEVAL, has been developed and preliminary analysis has been done to evaluate the financial return from various management regimes. The two management decisions having the greatest effect on timber quality are stocking, because it affects limb size, and rotation age, because it affects the proportion of juvenile wood. Because of the multitude of site conditions and management situations, no broad generalizations about optimal strategies are possible. A reassessment of silvicultural strategies may be needed for many lands in the Pacific Northwest to include new information on the effect these decisions have on timber quality and value.

Having better information about the effects of silvicultural regimes on wood quality and value creates the need for better information on other financial factors systematically affected by silvicultural regimes: management costs, logging costs, and manufacturing costs. It also points out the need to improve the capability to predict limb size resulting from different silvicultural regimes.

INTERNATIONAL COMPETITIVENESS OF SOFTWOOD EXPORTS FROM THE U.S. SOUTH

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FDC: 717: 722.1: 174.7: (73)

A growing number of softwood product firms in the southern United States view export marketing as a vital ingredient of future growth. However, there has been little study of the products and markets in which southern softwood producers have a competitive advantage.

The performance of southern pine lumber and plywood in foreign markets was examined from 1980 through 1985. These two products dominate softwood solid wood exports from the U.S. South, and the 1980-85 period provides a severe test of competitiveness because a rising U.S. dollar made these products more expensive in foreign currencies. U.S. export data show that while the value of southern softwood exports declined overall, they became increasingly concentrated in two principal markets, the European Economic Community (EEC) and the Caribbean. Also, southern pine lumber shipments to the Caribbean and southern pine plywood exports to the EEC rose 23 and 317 percent respectively, indicating possible competitive advantages in those markets. However, a definitive conclusion requires comparisons with competing softwood suppliers in the respective markets.

Market-share analyses were conducted to determine how U.S. exports of southern pine lumber and plywood performed relative to other softwood supplying regions and countries in the Caribbean and EEC markets during the 1980-85 period. Southern pine lumber exports to the Caribbean and southern pine plywood exports to the EEC rose while total imports declined; the resulting gains in market share indicate a competitive advantage for southern pine in those softwood product markets. Southern pine lumber lost market share in the EEC, indicating a lack of competitiveness in the EEC structural lumber market which the softwood lumber trade statistics reflect. Data were inadequate for assessing the competitiveness of southern pine plywood exports in the Caribbean; however, U.S. export data show shipments to this market increased slightly during the 5-year period.

Regional export performance can be enhanced by identifying foreign markets where specific products exhibit a comparative advantage. Market-share analyses for southern pine lumber and plywood indicate the U.S. South has a competitive advantage for supplying softwood lumber in the Caribbean and softwood plywood in the EEC.

FUTURE OF PULPWOOD IN WESTERN EUROPE

by
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FDC: 86: 722.1: (4)

The completion of the internal market is proceeding rapidly, though in the very moment nowbody can know which states it will comprise and how it will look like, regarding the movements in Eastern Europe. However, the pulp and paper industry in Western Europe is subject to remarkable changes. Mergers and acquisitions, modernization and, above all, meeting the challenges of many environmental issues take place. New pulping processes have appeared and shortly will be tested at plant level. Disposal problems enforce greater use of recycled fibre. Overproduction of food crops leads to efforts to utilize considerable areas for non-food purposes, which means reforestration in large scale on one hand and forwarding annual crops, which partly shall serve as fibrous raw material for pulping. And, last but not least, pulpwood prices in Western Europe are with a few exeptions, considered to be very high. To survive this disadvantage regarding international competitiveness has to be overcome by different strategies, e.g. by increased use of sawmill waste or fillers, coatings and pigments.

In 1988, Western Europe's pulp and paper industry (definition according to European Paper Institute) produced 19,6 mill. tons of chemical pulp and 12,4 mill. tons of mechanical pulp. This corresponds to about 125 mill. m^3 equivalent volume of wood in the rough, when using the conversion factors developed by the United Nations Economic Commission for Europe.

Demand for and production of paper and board is supposed to grow by an annual 2 % till the end of this century. Provided the fibre furnish remaines unchanged, this will require additional 34 mill. m^3 EQ.

On the other hand we can foresee some changes in the fibre furnish, which will reduce this additional demand for pulpwood. Waste paper is supprosed to increase its share. It can be estimated, that these impacts replace some 10 % of pulpwood.

The share of fillers and pigments in the fibre furnish of the German paper industry, which can be considered to be a forerunner of West European paper industry has climbed from 11,6 % (1977) to 17,6 % (1988) and it is still growing. Similar processes have taken place in other countries, too. That will cause an estimated reduction of pulpwood demand in Western Europe Europe by some 2 mill. m^3 EQ.

The EC-Commission plans to establish at least an area of half a million ha to grow annual crops for pulp. This potentially will replace one mill. of pulpwood.

WOOD TECHNOLOGICAL AND X-RAY DENSITOMETRIC STUDIES OF PINUS SILVESTRIS FROM A DAMAGED STAND

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FDC: 425.1: 425.3: 812.7: 815: 174.7 Pinus sylvestris L.

In northwestern Germany Pinus silvestris L. is a most important species with a wide range of wood quality. The deposition of air pollutants may result in decline of trees and changes of wood quality and the possible end uses. Wood properties of P. silvestris from damaged stands from different sites in northwestern Germany have been investigated in the institute of forest utilization of the university of Göttingen in an integrated project of the research centre for forest ecosystems*).

In this project severely damaged and undamaged trees from similar sites were compared for anatomical, physical and mechanical wood properties. In addition to that borings from 30 pines from the forest district of Sellhorn (Lower Saxony) have been studied x-ray densitometrically in the station de recherches sur la qualite des bois in Nancy. Here we present the within ring density of damaged and undamaged pines and their relationship to the strength properties.

In October 1985 15 undamaged and 15 severely damaged pines were sampled in a 93-year-old stand. Among other properties compression parallel to grain (DIN 52185), maximum load in bending (DIN 52186) and dry density (DIN 52182) have been assessed as well as maximum, mean and minimum density of growth rings and mean density of early and late wood of segments of borings (x-ray densitometry).

The sapwood of the damaged pines showed smaller growth rings with higher proportions of latewood and smaller contrasts of density and consequently more homogeneous wood than that of the undamaged ones. Cell walls were of equal thickness, but lumen diameters of the early wood tracheids of the damaged trees were smaller.

Strength in compression and bending of almost all cross section zones of the damaged pines was higher as a result of the more homogeneous structure of growth rings. This was to a great extent explained by the density of early wood alone in multiple linear regression analyses.

These results and the other findings of the project including the effects of storage of the same stems for one year show, that wood of severely damaged pines from stands affected by air pollution is of the same quality, especially concerning the strength properties, as that of undamaged trees and consequently the uses are not limited*).

*) Hapla, F., Knigge, W. and Nimmann, B., 1989: Untersuchung der Holzeigenschaften von Kiefern aus immissionsgeschädigten Beständen auf unterschiedlichen Standorten Nordwestdeutschlands. Berichte des Forschungszentrums Waldökosysteme, Reihe B, Bd. 11, Göttingen, 79 p.

A STUDY OF TURBULENT DYNAMICS OF A BAMBOO (PHYLLOSTACHYS PRAECOX) ECOSYSTEM

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FDC: 180: 172.5 Phyllostachys praecox

Based on the theory of ecoboundary system, the authors considered the dence canopy of a bamboo stand as an "ecological body" working as a unit, the interface layers between the canopy and its surrounding as an ecoboundary system complex and the distributional density of leaves and branches within the canopy as a compositional structure of the "ecological body". All these play an important role collectively in material exchange and energy flow of a bamboo ecosystem.

The turbulent fluxes are calculated by using the method of aerial dynamics in the atmospheric boundary layer. The results obtained indicate that, with the increase in solar radiation after sunrise, the upper part of the canopy is heated first, so the heat transfer is downward from the upper part of the canopy. It is also influenced by the temperature inversion layer near the floor from which a weak upward flux goes to the lower part of the canopy and a downward flux to the floor. At the pick of photosynthesis in the morning about 10 a.m. the canopy serves as a sink of CO_2 which comes from the atmosphere above the canopy and from the respiration of soil underneath; while at the "nap" period of photosynthesis at 2 p.m. the canopy becomes the source of CO_2, the excess CO_2 mainly goes downward. The transpiration of bamboo leaves and branches is very active in the afternoon. Heat, water vapor and CO_2 fluxes are all greater than those in the morning.

The authors also presented a new method to evaluate whether the turbulence would develop or not according to the figure patterns of temperature and wind profile in a bamboo forest area. The results show that in the midsummer, the turbulence is always developed after 11 a.m. out of the forest and is gradually disappeared after 4 p.m.; while within the forest, turbulence can not be developed all day long except at those moments when the thunderstorm is being occurred.

CHILE'S FUTURE ROLE IN PACIFIC RIM MARKETS

by Arnaldo Jelvez and Keith A. Blatner

FDC: 722: (83)

The presentation focuses on the perceptions of Chilean forest products exporters with regard to the current and future involvement of their companies in international trade particularly with the Pacific Rim markets.

A mail survey was used to canvas Chilean solid wood products exporters. Although the response rate (21%) was not particularly high, however, most of the major exporters responded to the survey, and companies of all sizes and major product lines answered the survey. The first part of the questionnaire queried exporters on various aspects of their current involvement in international markets. The second part focused on exporter's perceptions of opportunities for the expansion of solid wood products markets as well as the major constraints on the future development of their industry.

Japan is considered the most promising market for Chilean solid wood products. Radiata pine lumber, including rough green, finished and clears are considered the most promising of Chile's solid wood products markets over the next five years.

Respondents felt that additional government programs should focus on policies: designed increase available working capital, the country's infrastructure and overall monetary policy. Areas identified for private sector attention were quality control and marketing research.

STRUCTURE OF THE WORLD FIBRE-BASED PACKAGING BUSINESS

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FDC: 861.28: 71

The purpose of this research is to analyse the structure of the fibre-based packaging industries worldwide and to estimate the direction of the expected future development. This research focuses on the two main product groups of this industry: the containerboards and the boxboards. These two product groups have accounted for about 40% of the world total paper and paperboard production during the 1980s.

The role of fibre-based packaging is rapidly changing from that of transportation protection towards information carrying. Also, the fibre-based packaging industries are going through a restructuring phase judging by the numerous mergers and acquisitions presently occuring within the industry.

The main elements used in this study for describing the structure and business environment of the fibre-based packaging industries are: degree of concentration of fiber-based packaging industries and extent of vertical integration among converting industries in the main packaging markets. The database behind these structural analyses consists primarily of the business profiles of some 200 major producers of fibre-based packaging materials. These profiles include parameters describing the financial performance, fibre supply sources and the relative importance of the packaging sector for the major producers. An analysis of cost competitiveness among the major producing areas is also included in the scope of the research. All the above information is utilized when describing the present competitive environment and assessing the course of future business actions in the main markets for fiber-based packaging. This study is carried out on a worldwide basis but with a special reference to Western Europe, North America and selected major producing areas of fiber in Asia, Latin America, and Oceania.

PROBLEMS AND THE FUTURE OF WOOD DRYING IN INDONESIA

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FDC: 847: (910)

This paper describes the problems faced by the industry and the future of wood drying in Indonesia. The importance and contribution of wood drying in the wood industry in Indonesia has been recognized, although it is faced with varying magnitude of problems.

Problems faced by the industry arise from a body which responsible for quality control of wood products for export. Complaints also arise from buyers especially in Europe about moisture contents of lumber. New government's regulation that has raised export tax of sawn timber creates new problems with drying. The purpose of the regulation is to encourage export of mouldings and furniture, however these products will not readily be able to replace sawn timber as the principal commodity for export. The problems now is the lack of raw materials to feed the available space of kiln dryers.

It is anticipated that in the future there will be no major changes of drying methods as currently practiced, although there will be some changes in wood species and sizes to be dried. With an increase of the number of wood processing unit and wood finished products for export, there is a growing need to an efficient drying method in order to meet the quality of wood products.

PROPERTIES OF COMPOSITE BOARDS FROM GIANT PAULOWNIA WOODY BIOMASS IN EGYPT

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FDC: 862: 176.1 Paulownia fortunei: Hemsl.: (62)

The giant growth of irrigated paulownia plantations in Southern Delta trials of the Ministry of Agriculture and Land Reclamation suggest the current investigation. This newly introduced species from China proved to establish successful giant trees in irrigated plantation in Egypt.

Trees were felled from a one year old Paulownia fortunei plantation. Sampled trees were then processed for composite board production. The giant juvenile growth of this species resulted in a total height of 5.6 M with 0.058 M^3 above ground wood volume. Total woody biomass was used to produce boards at board density of 630 Kg/M^3. Wood biomass of Paulownia was chipped, dried up to 3.5% MC and resin coated with 1% urea formaldehyde resin. Two levels of resin were used for processing the material.

Mechanical behavior testing showed that the MOE and MOR were 38900 KP/cm^2 and 237.2 Kp/cm^2 respectively. This showed a statistically significant increase than boards produced from three year old casuarina. However, the casuarina boards were slightly higher in the internal bond value.

These obtained results indicate the suitability of Paulownia for composite board production. In view of the giant growth of this multi-purpose tree species and current findings, it is clear that it could provide an economic solution to the timber shortage problem in the country.

COMBINED EFFECTS OF AIR POLLUTANTS ON TREE RING STRUCTURE AROUND STEAM POWER PLANTS NEWLY BUILT IN JAPANESE RURAL AREAS.

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FDC: 425.1: 425.3: 811.4: (52)

Relations between the intensity of combined air pollution and tree-ring structure have statistically been analysed in two rural and seashore areas; A (Awara, Fukui; Japan Sea side) and B (Kashima, Ibaraki; Pacific Ocean side). Steam power plants were newly built in both areas in the 1970's, and they were regarded as a main source of air pollution.

In the area A, a total of 270 increment cores was collected from Cryptomeria japonica trees at 51 sites. Past changes in tree growth without climatic and aging influences were estimated by SRI (Standardized Ring Index), which was statistically obtained from the original ring widths. After the power plant started its operation in 1972, the SRI decreased clearly near the plant. The evident decrease was observed within 8 km from the plant, and not contradictory to the calculated diffusion of the air pollutants. The SRI correlated with the annual mean of both SO_2 and NO_2 intensity, and 70% of its variation was statistically accounted for by both pollutants. A scrubber system was newly installed in the chimney of the plant on July, 1975, and the emission of SO_2 thus reduced. A recovery in SRI was clearly observed within 5-9 km from the plant since 1977.

In the area B, a total of 140 increment cores was collected from Pinus densiflora trees at 14 sites. Synthetic indicators of tree-ring characteristics showed a significant correlation, at over 98% confidence level, with the total of the daily maximum concentration of SO_2, ozone, NO and NO_2. This shows that pine growth must be affected by combined effects of air pollutants in this area. The annual mean of the SO_2 intensity increased after the factories started their operation since 1970, and reached its peak in 1973. From 1976, the factories including a steam power plant started to consume low sulfur crude oil, namely oil containing 0.3% instead of 1.5% sulfur. The annual mean of SO_2 decreased evidently from 1977. A recovery of the synthetic indicators of tree-ring characteristics was observed within 7-9 km from the power plant since 1977.

It was ascertained that reducing only SO_2 emission can strongly decrease combined effects of air pollutants upon tree growth. We believe that a technical effort to reduce at least SO_2 emission should be carried out quickly to stop worldwide forest decline.

ZEPHYR WOOD, A NETWORK OF CONTINUOUS FIBERS

DEFIBRATION OF WOOD BY ROLLER CRUSHING AND RECOMPOSITION OF IT

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Japan

FDC: 862.3: 812

An attempt was made to manufacture zephyr, a network of continuous fibers, by roller crushing of small-diameter thinnings from forests and of waste slabs from sawmills and then to produce the improved wood (zephyr wood) using zephyr as a raw material modeled on plywood making.

Small-diameter logs and slabs, in the process of being crushed by rollers, decrease in thickness and increase in width, and are thus turned into a new material having a larger surface area than the irregular-shaped original materials. Shape of the pressing rollers, interval of the rollers in relation to the thickness of the material, number of times of roller passes and so forth required careful study and attention.

6 zephyr sheets were glued into zephyr wood, like as gluing veneer into plywood. As zephyr wood surface layer, 2 sheets were set up in parallel with zephyr wood surface direction. And as a core layer, 2 sheets in cross direction and as a back surface layer, 2 sheets in parallel direction were set up. The thickness of the board was controlled with metal stops used along the edge of the platens in press, then initial board forming pressures were from 7 $\mathrm{kg/cm^2}$ to 5 $\mathrm{kg/cm^2}$.

Because zephyr thus produced has a continuous grain running in the fiber direction, it was expected that it could be recomposed into boards with good tensile and bending strengths as needed in a board material. However, because of internal splits that appeared in the course of production (which are equivalent to lathe checks in veneers), it was feared that shear strength perpendicular to the board surface would be rather small unless the resin content in the adhesive used was large. Tests conducted on the boards, all confirmed what was anticipated. As a board material, it had bending strength comparable to plywood, but perpendicular to its surface, strength was lacking.

Table 1. Some mechanical properties of trial-manufactured zephyr wood (board).

Species	Thickness (mm)	Swelling treatment	Adhesive	Resin content (%)	Specific gravity	Static bending		Shear strength ($\mathrm{kg/cm^2}$)	After 4 hrs boiling	
						MOR ($\mathrm{kg/cm^2}$)	MOE ×1000 ($\mathrm{kg/cm^2}$)		Shear strength ($\mathrm{kg/cm^2}$)	Thickness swelling (%)
Hinoki	12 (1)	10% PVA	Isocyanate	5.7	0.57	546	94.6	7.1	4.6(7)	21.6
〃	〃 (1)	〃	〃	7.0	0.66	756	96.2	9.2	4.7(7)	18.3
〃	〃 (1)	10% Urea	〃	6.7	0.55	395	62.2	7.8	0.7(7)	25.0
〃	〃 (1)	〃	〃	6.7	0.66	470	93.3	8.6	0.6(7)	17.3
Sugi	〃 (1)	〃	〃	6.3	0.57	464	82.0	6.2	0.5(7)	17.3
Hinoki	〃 (4)	5% PVA	Urea	6.3	0.58	228	25.8	3.9	—	27.3
〃	〃 (4)	〃	〃	7.0	0.57	266	30.6	6.2	—	28.9
〃	〃 (4)	5% Urea	Urea-melamine	9.8	0.54	173	33.9	4.5	—	30.1
〃	〃 (4)	〃	〃	9.8	0.59	251	29.6	5.1	—	23.0
〃	〃 (4)	〃	〃	11.2	0.65	344	53.4	6.8	—	22.4
〃	〃 (4)	〃	〃	11.2	0.70	335	44.8	8.2	—	29.9
〃	19 (5)	2% Urea	Urea	7.7	0.55	427	42.4	2.2	—	—
〃	17 (5)	〃	〃	6.8	0.57	395	44.3	1.7	—	—
〃	16 (5)	〃	〃	7.5	0.64	488	62.9	2.6	—	—
Sugi	14 (5)	〃	〃	11.3	0.70	530	85.5	4.1	—	—

(7) After a cycle of 4 hrs boiling, 20 hrs drying, and 4 hrs boiling.

THE DEVELOPMENT OF PARTICLE BOARD AND INORGANIC BONDED BOARD RESEARCH AND INDUSTRY IN INDONESIA

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FDC: 862: (910)

This paper discusses the development of particleboard and inorganic bonded board research and industry in Indonesia. Until now, Forest Products Research and Development Centre (FPRDC) has conducted investigation on 20 wood species from 58 Indonesian wood species which studied, met FAO standard for making particleboard and 94 wood species from 223 Indonesian wood species, met DIN 1101 standard for making wood wool cement board.

At present, Indonesia having 7 particleboard and 5 wood cement board factories with total installed capacity 243,000 m^3 and 147,350 pieces (dimension: 2 mx 0.5 m x 2.5 cm) respectively. The problems of development of particleboard and inorganic bonded board industries are quality, lack of technology, wood species which are suitable for particleboard and inorganic bonded board, and the marketing problem.

THE EFFECT OF JUVENILE WOOD ON GRADING OF FAST GROWN NORTH AMERICAN SPECIES

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FDC: 811.53: 815: 238

In order to satisfy the increased demand for forest products while addressing environmental concerns, much of future timber supply will be from improved trees grown on managed plantations. These trees will be harvested in short-rotation cycles and will contain larger than normal quantities of juvenile wood. This talk will address what influence juvenile wood has on the structural performance and implications for the grading of dimension lumber. The results are of significance to all producers because of concern that the lumber from the fast-grown plantations may have lower mechanical properties than indicated by current design codes.

Early research on anatomical characteristics and mechanical properties of clear wood demonstrated that juvenile wood of soft wood species is substantially lower in mechanical properties than mature wood, and generally accounts for the inferior properties of plantation grown trees compared with those grown in natural forests. Because of these early research results, there are concerns that allowable stresses assigned to lumber do not adequately reflect the changing resource. In the 1980's, researchers began to directly assess the mechanical properties of this material.

The literature indicates that lumber cut from the juvenile wood zone of logs obtained from young-growth plantations, at least for Douglas-fir and Southern Pine, may not meet current design requirements. Reported ratios of 2x4's containing all juvenile wood to those containing all mature wood strength and stiffness values have ranged from 45-59 % and 51-72 % respectively. Juvenility appears to be more severe in the Southern Pines than in Douglas-fir and modulus of elasticity (MOE) is influenced more by juvenile wood than is strength.

Current visual grading rules in the United States and Canada such as restrictions on growth characteristics and lightweight wood, knot size and slope of grain do not separate juvenile wood from mature wood. To accommodate the new plantation resource, it appears that grading rules and/or allowable design stresses will need to be modified. The objective of new grading practices will be to downgrade those pieces that do not conform to design and at the same time minimize the downgrade of pieces that do meet design. In visual grading percentage late wood, rate of growth, specific gravity, and the presence or absence of the pith all relate to juvenility and show some potential for identifying low strength/low stiffness pieces. These physical properties used individually as sorting criteria, however, are costly to yield due to considerable overlap between the property distributions for pieces that conform to design and those that do not. More work is needed understand the impact various combinations of anatomical predictor variables can have when supplementing visual grading techniques.

It appears that currently machine stress rating holds the most promise for maintaining a specified strength level. MOE changes encountered with juvenile wood can be handled by automatic procedures that include MOE measurements. Research also indicates that ratios between lumber strength properties are not greatly affected by the presence of juvenile wood.

INTEGRATING AN INTELLIGENT MULTI-CHANNEL WOOD MOISTURE METER INTO A DISTRIBUTED WOOD KILN DRIER CONTROL SYSTEM.

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FDC: 847.2: 812.210

The latest trend in wood drier kiln automation is to make use of conventional off-the-shelf controllers connected via an industrial network to a central IBM-compatible supervisory computer. The central computer serves as the intelligence centre where new setpoints are generated. Drying schedules used in these particular applications are time based and does not provide any information on the woodmoisture content of the lumber charge.

A multi-channel intelligent wood moisture meter, as developed by the Department of Woodscience at The Faculty of Forestry of the University of Stellenbosch, is incorporated into a distributed wood drier kiln control system where three kilns are controlled by the same computer. Each kiln is equiped with its own moisture meter and is connected to the supervisory computer by means of a standard RS422 datalink. The multi-channel wood moisture meter collects data of selected boards in the kiln charge. This data enables the supervisory computer to exercise close loop control of the drying process by making use of wood moisture content as input parameter. In this particular application use is made of three moisture meters each fitted to a specific kiln and integrated into the distributed control system.

Quality and Grading of Fast Grown Norway Spruce (Picea abies Karst.). Lackner, R. (The Norwegian Institute of Wood Technology, NTI, P.O. Box 113, N-0314 Oslo 3, Norway.)

FDC: 815: 238: 854.21: 174.7 Picea abies Karst.

Most of European grading rules for structural softwood are based on data collected from first growth material. In future, the amount of re-afforested and extensively cultivated, fast growing forests will increase.

In Norway, e.g. the whole west-coast region (approx. 300.000 ha) was afforrested with European Spruce, mostly Picea abies Karst., in 1920-30. The timber is now mature for harvesting and provides some 50.000 m3 sawlogs per year.

The question has been raised whether this "new" material is of the same quality (strength and stiffness) as timber from first growth stands, and if the grading rules still are valid for this material.

Structural timber (360 boards and planks) in 2 dimensions, from 2 sawmills and in 3 grades have been re-graded visually and by Computermatic stressgrader according to the Nordic Grading Rules, and several parameters have been investigated, such as density, rate-of-growth, knot-area-ratio, bending strength and Modulus-of-Elasticity.

Quality of structural softwood timber from fast grown forests is found to be significantly lower than for "indigenous" material. Grading visually does not give satisfactory results. The only way of reliable grading is by means of a machine stress grader.

EVALUATION PRECOCE DE LA DENSITE DU BOIS DE CLONES DE *Eucalyptus grandis*

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SUMMARY

FDC: 181.51: 176.1 *Eucalyptus grandis* Hill ex Maiden--015.26

Evaluating as early as possible the basic density of *Eucalyptus* wood is of fundamental importance in many areas of the forest activity, both because this tree is the mostly planted in Brazil and because the density is the principal index of wood quality. The wood basic density was investigated in clones of *Eucalyptus grandis* aged of 9 to 21 monthes after the cutting of the buds in the mother-tree. It could be observed that: 1- It is possible to estimate very early the wood basic density of the *Eucalyptus* clones with the use of equations. The most safe results were obtained with the shorter intervals between the samples. The quadratic model, and in one case the cubic model, were chosen to represent the relation between the densities; 2- the average basic density of the clones increases with the age of sampling, and tends to become constant at the age of 21 monthes; 3- the average basic density of the seven clones can be estimated from the age by the following quadratic equation: $DB=0,01328+0,04724.I-0,00117.I^2$; 4- the average basic density of each of the clones can be estimated from the age by quadratic equations.

Keywords: evaluation précoce, densité basale, clone

THE USE OF BAMBOO AND PINE TIMBER AS WATER CONVEYANCE TECHNOLOGY

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FDC: 833.8: (678)

Among the problems facing some of the developing countries are on procurement of cheap water construction materials and the use of suitable local technology that can be locally developed.

For the past 15 years Tanzania has successfully researched and developed an appropriate technology of using bamboo pipes pine timber pipes and storage tanks that could be used as water supply transmission mains, water storage, food storage, irrigation mains, sewerage disposal mains, hydropower water transmission mains and road culverts. The achieved results are positive in the fields of Forestry, Engineering, Sciences, Economics, Sociology, Public Health and Public Service General. Both Bamboo and Pine Wood Forests are plentifull in the tropical areas where most of the developing countries are found, thus guaranteeing long future uses of these technologies.

The cost benefit achieved as compared to conventional used technologies e.g. Plastic, Concrete and Steel is 4 to 6 times cheaper when using bamboo and about 4 to 12 times cheaper when using timber insteady of conventioned products. The Bamboo and Timber Technology has been evaluated by local and external independent missions. As well a market study was done. Both reports are positive for Tanzanias situation. On hydraulic pressure capacity bamboo and sealed pine timber products can sustain pressure of 4 bars and 10 bars for bamboo and pine timber respectively.

The safe and effective preservation technique for bamboo and pine timber products has been investigated and successfully applied under different field situations. Approved Laboratories institutions have issued some formal approval on applied tecnics and its safety to mammal health. The life expectancy of a proper preserved material using bamboo and timber technology is 15 to 20 years for bamboo and up to 50 years for pine timber products.

In material processing for both products e.g. "Bamboo and Timber" the local rural areas workers are used because of the simplicity of the technology. Bamboo Pipes manufacture and construction is labour intensive activity while timber products and construction are of normal Sawmill activity consisting of a four cutters planner and carpentry field workers at construction sites.

NOISE REDUCTION IN SAWMILLS
Local collaboration around a reference-plant

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FDC: 30: 832.1

Noise has since long been considered one of the major work health problems in sawmills. It can be curbed by a systematic method involving various tests and experiments on site. By these, the various sources of the noise are separated and their magnitude measured. Possible ways of reducing the noise are studied on site in the plant with a minimum of disturbancies for the production. By involving the safety engineer and the actual machine operator, local participation in the curbation work is achieved. Provisional/experimental measures are transformed into permanent ones, that productivity criteria can accept. They can to a large extent be built/installed by the company's own (maintenance-)personnel and often at moderate costs. By working in a regional group of same 10 industries/sawmills mutual collaboration and exchange of knowledge and ideas is encouraged as well as endurance in the work. With this systematic method safety engineers are trained to curb noise with a maximum benefit/cost value. Also, manufacturers of sawmilling equipment are encouraged - or rather challenged - to modify their designs towards more silent machinery, once the sawmillers/customers have learnt the difference and designers are informaed about the possibilities.

FROM THE CONCEPTION TO THE CONTROL SYSTEM OF A FLEXIBLE WORKSHOP LINE FOR THE WOOD INDUSTRY

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FDC: 832.14

The wood production industry presents a certain number of peculiarities which up to now have limited in integration and automatisation. The production speeds are much greater than those for metal, where the majority of operations are conducted continiously, the rest only being interrupted where transfer problems arise. The material introduces contraints of putting into service differences of for example : deformation, heterogeniouty, anisotropy. At present the level of automatisation in the wood industry is in the form of isolated numerical control machines (positionning and shaping) or ever specialised lines which regime configuration at times. In one flexibility objective, a production line adapted to large pieces of any form of wood, is being developped, we have to choosen and adapted the conception tools at each stage of the realisation.

One hierarchic approach has been adopted for the conception and physical dimensionny of the system (SADT Method). This enables us to put in evidence the needs and flow of information and thus to structure the control of group in the aim modularity, adaptability and flexibility. A method control is proposed permitting the introduction of degrees of liberty on a linear structure which does not, in general, accept them. This necessitates some transfer and dynamic stockage of piece (SIMAN software).

Time configuration is determined by flow simulation technic. It allows to show utilization rate of each machine dynamic behaviour, bottle necks with differents types of pieces scheduling. In order to get scheduling automatically with have define a specific data bases structure which is well fit with wood machining. A piece is define by a gathering of machining type in a cartesian coordonates system linked to itself.

RELATION BETWEEN VISUAL CHARACTERISTICS AND PSYCHOLOGICAL IMAGES OF WOOD GRAIN FIGURES

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Why we love grain figures?

FDC: 862: 812.11

The main cause might exist in visual mechanisms: e.g. wood figures consist of non-crossing lines or curves - these are perceived agreable; deviations and variations in annual ring width - perceived as natural; anisotropy of light reflectance and wood colours of predominantly yellow and red hues - perceived as warm; and so on.

Fundamental studies of these relations and digitization of the figures and patterns were carried out.

Influence of particle orientation and particle size on psychological images of particle board as well as the influence of groovees and knots in interior wall panels were also investigated.

USERS' NEEDS FOR WOOD QUALITY OF PLANTATION-GROWN TREES IN HOKKAIDO

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FDC: 815: 238: 174.7 Cryptomeria japonica D.Don: 174.7 Chamaecyparis obtusa Sieb. et Zucc.

There are more than 10 x 10^6 ha artificial forest, mainly consisting of sugi (Cryptomeria japonica) and hinoki (Chamaecyparis obtusa) among the total forest ares 25 x 10^6 ha in Japan. These two main species are very useful trees for structural use, especially for columns of traditional Japanese wooden houses in which wooden columns are visually appreciated. As the users need clear columns, pruning is the most important silvicultural treatment.

As Hokkaido is located in the northern part of Japan, sugi and hinoki are not available there except in a very small area of the south because of weather conditions. Main species for plantations in Hokkaido were todomatsu (Abies sachalinesis) and karamatsu (Larix kaempferi) till about 10 years ago. At present, almost only todomatsu is planted. Why was karamatsu rejected? Because an about 10 cm x 10 cm cross section lumber with pith sawn from a small log might twist after drying, and other defects such as surface check due to drying were larger than those of lumbers from natural todomatsu trees.

From my research results concerning growth and wood quality of planation-grown todomatsu, I have pointed out that this species has many defects. These are: (1) Very many trees have wet wood around dead branches in heartwood. It suggests the high possibility of frost crack occurring in the trunk. In fact, many old-planted todomatsu trees have frost crack(s) in trunks. (2) There is very low density wood, which is lower than 300 kg/m^3 in basic density. (3) Almost all of square-sawn lumbers with pith or those taken from near the pith may twist after drying just like karamatsu does.

For the reasons mentioned above, I have suggested that todomatsu is not a good species for plantations in Hokkaido and that karamatsu is better because the density if higher; and nowadays, the technique for utilizing karamatsu is almost perfected developed.

THE OIL PALM STEM - A POTENTIAL LIGNOCELLULOSIC RESOURCE FOR THE WOOD-BASED INDUSTRIES

by

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Summary

FDC: 861.0: 175.2 Elaeis Jacq.

The abundant availability of oil palm stems in Malaysia coupled with the growing scarcity of tropical timbers has given rise to the need for a closer look at the oil palm stem as a possible source of raw material for the country's wood-based industries.

This material is different in many ways from normal wood in physical and chemical characteristics such that its processing and treatment pose an enormous problem and call for an entirely different approach, depending on the end-products.

Based on present findings, the oil palm stem has a very limited application for lumber. Only certain parts of the stem can be processed into solid timber, and even then special care has to be taken in drying and treating the palm wood. Claims have been made of a break-through in the making of furniture but these await verification.

The most promising use of the oil palm stem lies in its comminuted form whereby the main two structural components, the vascular and parenchymatous tissues can be partially separated. For most purposes as in pulping and papermaking and the manufacture of panel products (wood particleboard, cement and gypsum bonded particleboard, fibreboard), this segregation to recover the vascular bundles is essential to yield acceptable products. There are many ways of effecting this separation depending on the end-products which dictate their tolerance of the parenchymatous tissue.

Although the technical feasibility of utilising the oil palm stem for some of these wood-based products has been established , refinements are still necessary especially in the designing of suitable processing equipment and in the reduction of the high cost involved in the extraction and transportation of the fresh material from the fields. Only then can the oil palm stem serve as an attractive alternative raw material resource for the wood-based industries.

ON THE MECHANICAL PROPERTIES AND ANATOMICAL RELATIONSHIP OF SOME NATURAL STAND MALAYSIAN BAMBOOS

by

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Summary

FDC: 815: 812.7: 811.1: 175.2

This report includes the anatomical characteristics and mechanical properties of one to three year old natural stand Bambusa blumeana, Bambusa vulgaris var. striata and Gigantochloa scortechinii. Mechanical properties such as shear, compression parallel to grain and static bending were correlated to anatomical properties, such as vascular bundle size and distribution and fiber dimensions. Results showed that there is an increase of compressive and bending strength with age and height of the culms. This pattern could be related to the significant increase in vascular bundle size and distribution.

This test further indicates that age is an important factor as it not only influence the mechanical and anatomical properties, but also the suitability and durability of bamboo especially for construction and manufacturing purposes.

RATTAN PROCESSING INDUSTRY IN PENINSULAR MALAYSIA - ITS STATUS, PROBLEMS AND PROSPECTS

by

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Summary

FDC: 892.82: (595)

The results obtained from a four year survey programme conducted (June 1985 to June 1989) on rattan processing industries in Peninsular Malaysia are discussed. The survey showed that rattan processing mills are concentrated in areas having bigger forest areas and better infrastructural facilities.

Out of 563 mills surveyed, 15.5% are engaged solely in processing, 71.9% on finished products and 12.6% in both processing and manufacturing of rattan products. The survey also showed that the majority of the mills are small-scale, with full time workers ranging from 4 to less than 10 persons.

Various problems being faced by the industry include lack of continous supply of higher grade of commercial rattan species, marketing, low technology, difficulties in obtaining skilled workers and high wastage.

Keywords:

- Distribution of rattan processing industries
- Classification of rattan processing mills
- Low cost automation

GENETIC VARIATION OF WOOD DENSITY IN PROGENIES OF *Eucalyptus grandis* HILL EX MAIDEN AND ITS RELATIONSHIPS WITH GROWTH CHARACTERISTICS

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FDC: 165.51: 812.3: 181.65: 165.62: 176.1 Eucalyptus grandis Hill ex Maiden

Genetic variation of wood density and other growth characteristics such as height, d.b.h. and volume has been reported in open polinated progeny trials of *Eucalyptus grandis* Hill ex Maiden, from phenotypically selected whithin a base population settled in Mogi Guaçu-SP and Salto-SP, in Brazil. Progeny tests were established three sites: Anhembi, Brotas and Lençóis Paulista, in November, 1976. An 8 x 8 triple lattice design was used. The 64 treatments consisted of progenies of selected trees from the base population, progenies of other populations, commercial controls and base population without selection.

The development of the progenies in all three sites at seven years was satisfactory so that the best averages for growth characteristics were obtained in Anhembi, and wood density presented highest average in Lençóis Paulista. Wood density presented significant genetic variation in all sites, while for growth characteristics these variations showed to be less significant.

The importance of progeny x site interaction was determined in joint analyses envolving the studied localities. Wood density was the characteristic which suffered the least influence of this interaction, as shown by progeny x site interaction variation coefficient. Among growth characteristics height was the least influenced by environments. The progeny x site interaction reduced the heritability values, and, therefore, affected selection gains. This reduction was wider for volume followed by d.b.h. and hight. Wood density presented the slightest reduction.

Growth characteristics presented high phenotypic and genotypic correlations, although concerning to density these correlations were negligible. The correlated response results showed that indirect selection for hight provide higher gains for d.b.h. and volume than direct selection for a these characteristics. Selection for wood density would cause more damage to growth characteristics than the selection of such characteristics causes for wood density.

Some improvement strategies have been proposed such as the selection of height among and within progenies, thus converting the progenies test into a Seeding Seed Orchard; similary, best trees and progenies for wood density would be selected and propagated vegetatively for the formations of a Clonal Seed Orchard. Another alternative would be selection for height between progenies and for wood density within such progenies, to establish Clonal or Seedling Seed Orchard.

CORRELATIONS OF TRAITS IN TAMARACK
(*LARIX LARICINA* (DU ROI) K. KOCH)

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FDC: 165.5: 181.51: 165.62: 174.7 *Larix laricina* K. Koch

Tamarack is considered to be a species of increasing economic importance and is included in silvicultural and breeding programs in most provinces of eastern Canada and in some states of the northern U.S.A. Stem form and rate of growth are the major traits to be improved. To estimate genetic parameters for family and clonal selection a pilot-scale experiment was developed.

Seedlings from 7 stands with 7 trees each in New Brunswick and Maine were grown in a greenhouse and multiplied by rooting of cuttings to produce 490 clones. A field experiment was planted near Fredericton and measurements made at age 5 years from seed. Measurements included total height (HT), stem straightness (STEM), leader damage (LEAD) from deer browsing and insects, and percent survival (SURV). Analyses of variance were performed and mean squares for family effects were statistically significant at the 1% level. Variance components were substantially larger than their standard errors for all variables.

The table below gives genetic correlations (upper triangle) based on family variances and covariances and phenotypic correlations calculated from family means over all replications (lower triangle):

	HT	STEM	LEAD	SURV
HT	-	0.078	-0.319	-0.539
STEM	0.007	-	0.124	-0.429
LEAD	-0.144	0.153	-	-0.891
SURV	0.059	-0.007	-0.065	-

It is evident that there is no negative genetic correlation between height and stem straightness which would facilitate simultaneous selection for both traits. The other genetic correlations are of lesser interest and probably have been influenced substantially by early establishment conditions including damage by deer in this particular area. None of the phenotypic correlations are large and significant. These preliminary results are encouraging but must be verified by subsequent measurements, and the analysis of a companion experiment.

Dr. K. Carter, University of Maine, participated in the development of the experiment and her contributions are gratefully acknowledged.

CONVERSION OF MIDDLE DIAMETER SUGI LOGS INTO SAWN LUMBER
-SAWING YIELD BY USING SAWING PATTERNS IN CONSIDERATION OF LOG QUALITY-

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FDC: 822: 832.181: 174.7 Cryptomeria japonica D. Don

It is very important in conversion of logs into sawn lumber using a sawing pattern to consider not only end uses, sawing efficiency, and yield but also log quality. Until now we can find only few data on the lumber yield considering log quality. The lumber yield from middle diameter sugi (*Cryptomeria japonica* D. Don) logs was investigated using sawing patterns in consideration of log quality.

270 sugi logs (3.7 or 4.0 m in length) were divided into two top diameter groups, 18-22 cm and 24-28 cm, and their numbers were 152 and 118, respectively. All the logs were graded by means of Japan Agricultural Standard (JAS). Then, they were converted into sawn lumber, mainly construction members, with two band saw machines by using the sawing patterns in consideration of log quality. After all the sawn lumber was graded by means of JAS, volume and value yields from each log were estimated.

When the logs were classified into three classes, A, B, and C, by "yakumono" (special grade lumber for appearance use in Japanese houses) output percentage, the differences in the average volume yields were not evident among three classes. On the other hand, there were significant differences in the average value yields among them, that is, the average value yields of A, B, and C class were attained to 95%, 70%, and less than 60%, respectively.

Although, number of knots on the log faces had few influence on the volume yield, it influenced on the value yield. More than 75% of value yield is expected from higher quality logs than those which have neighboring two log faces, however, it is difficult to obtain high value yield from lower quality logs. This may be one of the effective indications for selecting sawing patterns on the standpoint of the importance for the value yield or the sawing efficiency.

Table. The average yield from middle diameter sugi logs (%).

Top diameter	18-22 cm			24-28 cm		
Class*	Number	Volume	Value	Number	Volume	Value
A	24.3	63.8	97.8	45.8	64.1	94.9
B	12.2	60.4	72.5	16.1	60.6	69.7
C	63.5	63.9	57.6	38.1	65.2	58.4
Overall	100.0	63.4	69.2	100.0	64.0	76.9

*:Classified by "yakumono" output percentage. Those of A, B, and C classes are more than 25%, 15-25%, and less than 15%, respectively.

MODELLING WOOD QUALITY USING A NEW SOFTWARE : A SYNTHETIC APPROACH

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FDC: 85--01

A first, the authors present a new software built by INRA (Wood Quality Research Laboratory). This software allows to describe any board sawn in tree for which and intensive description is available (branching, distribution of ring width, ...). At present software allows to give knottiness, grain angle and ring width for any location in the board and so, allows to grade such board in accordance with grading rules based on those characteristics.

Secondly, the authors describe researches presently done in view to feed the software with realistic description of the standing trees. Aim of these researches is find statistical relationships between intensive description (presently needed in view to feed the software) and realistic description of the tree or tree population (size, age, living crown percent, ...).

Those relationships will be introduced in the software in view to use it realistically (knowledge of quality of available wood resource in relationship to silvicultural practices, ...).

Some results (modelisation of the branching, modelisation of intra-tree wood density, ...) gained on Norway spruce are presented.

Thirdly, present and possible developments of this tool are discussed. Such developments are based on the fact that detailed description of board given by the software could allow to predict technological ability of the board. First result is presented (Young modulus prediction of wood piece sawn in given tree).

Future prospects for using of the solftware are discussed (prediction of board deformations after during, prediction of sliced or peeled veneer figure, ...).

In conclusion, the authors underline that promising developments of the tool depend on close relationships with people involved in forest and wood sciences in view to get biological and mechanical models needed.

THE REDUCTION OF GROWTH STRESSES AND MOISTURE CONTENT IN LOGS DURING DIRECT HEATING

by
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FDC: 847.2: 812/813

The direct heating of logs (smoking method) carbonizes the surface of log and causes surface splits. But the treatment which is operated by a suitable schedule decreases and equalizes the moisture content in the log satisfactorily and reduces its residual stresses without giving serious damages.

This paper deals with the quality change of log during the direct heating.

In this treatment, green logs are exposed to high temperature smoke in a special kiln with a combustion furnace in which a low-cost fuel like scrap wood is burned. The temperature and the period of the treatment are roughly controlled by regulating the supply of air to the furnace. The highest temperature in the kiln is 150-200 °C and the practical treatment period is 2-4 days, they depend on the species and diameter of the logs.

The quality changes investigated here were as follows : moisture content distribution, degree of surface splits, residual stresses, crook at sawing, strength properties, color of wood, change in the chemical compositions and thermal softenings in wood powder and in milled wood lignin. The tested species were Japanese cedar(Cryptomeria japonica D.Don), J.larch(Larix sp.), J.beech(Fagus crenata Blume) and Zelkova(Zelkova serrata Makino).

Moisture content in the logs was reduced and the distribution across the diameter was changed into an even pattern. The reduction of strength properties was recognized in the case of tension parallel to the grain but there were no changes in the strength for bending, compression and shearing. The residual stresses (released strain) in the treated logs became less than half as much as that in non-treated logs and the stress gradient across the diameter in the treated logs became half as well, then crooks at the time of sawing also was halved.

The treatment of 30-35 hours at temperature above 80 °C inside log was a fair condition common to the all species used here. The bark, insulating the xylem from direct exposure to the high temperature gas, restraining an excessive evaporation from the surface of the log, preventing the generation of drying stresses, protects the log from the serious surface splits.

Within this condition, serious changes were not recognized in the color and the chemical compositions. Considering the hygrothermal softening temperature in wood powder and in MWL, the lower temperature than this would be sufficient for reduction of the growth stresses.

A dry heating of logs like this would be profitable for pre-drying and reduction of loss by crooks at sawing. This method has the utility merit for preventing the waste of forest resources with too much energy consumption or water pollution, unlike steaming or boiling logs.

Etude dendroclimatique du bois de Taxus baccata du Nord de l'Iran[1]

par

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Résumé:

FDC: 811.4: 111.82: (55)

Nous avons choisi 11 arbres de Taxus baccata du Nord de l'Iran pour étudier les relations existant entre les diverses caractéristiques du cerne et les facteurs du climat. Nous avons utilisé la méthode radiodensitométrique pour mesurer les caractéristiques des cernes annuels. Ensuite, on a dressé les courbes des chronologies moyennes indexées (selon Hugershoff). Enfin, nous avons calculé les coefs. de corrélations et les caractéristiques du cerne. Ces diverses opérations nous permirent d'établir 10 modèles climat-bois. Les résultats nous ont montré que:

- L'effet commun de deux ou plusieurs mois durant la période végétative est plus intense sur les caractéristiques du cerne que l'action séparée de chaque mois (à l'exception de l'influence significative des précipitations de mai sur la largeur du bois final).
- La température moyenne en février-mars a une action positive sur la largeur du bois initial, sur celle du cerne et sur la densité maximale (figure 5). Ces relations sont si étroites que l'on pourrait se servir de la courbe de la largeur du bois initial ou du cerne à la place de la courbe des températures. Ce fait est très intéressant au point de vue d'une étude climatologique des temps passés.
- L'augmentation de la pluviosité au cours des mois de mai et juin provoque un accroissement de la largeur du cerne et du bois initial, mais une diminution de la densité minimale.
- Dans l'ensemble de la région étudiée, la croissance en diamètre de l'if dépend plutôt de la température des premiers mois de la période de végétation que de la pluviosité. Cette dernière favorise la continuation de la croissance lorsque celle-ci fut rapide au printemps.

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Strength and grading of large dimension spruce lumber.

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FDC: 833.121: 854.21: 174.7 Picea abies Karst.

For many years Swedish sawmills have based their production on small dimension logs. However, the supply of larger logs has recently increased. The sawmills do not want to saw small dimension lumber from large sawlogs. They want instead to saw large lumber from large logs but claim that the market does not require large dimensions. The machine stress grading of large dimension lumber results in a low yield according to some sawmills.

The main purpose of this pilot study was to investigate the strength, stiffness and grading results of beams from large dimension lumber.

We started with 26 logs with a minimum diameter of more than 550 mm. 104 beams with a cross-section of 70 x 295 mm^2 were then cut and planed from these logs. The length of the available logs determined the beam length which varied from 4.8 to 5.4 m. All the beams were tested in bending. The results expressed in mean values are: bending strength 27 MPa, modulus of elasticity 9600 MPa. The mean value of the annual ring width was 4.1 mm (normally 2-3 mm) and the density 325 kg/m^3 (normally 400 kg/m^3) which indicates that the raw material came from trees that had grown far more rapidly than normal Swedish spruce (Picea abies). This may also explain the relatively low strength and stiffness values. All the beams fulfil the strength and stiffness requirements for the lowest grading class for Swedish structural timber. The results indicate that the strength and stiffness of normally-grown spruce lumber is sufficient.

Before testing, the beams were stress-graded according to three different grading rules: machine stress grading and visual grading according to the Swedish T-rules and the ECE-rules. The two visual methods classified the beams in an acceptable manner, while the machine stress grading underestimated beam strength.

The calculations of the correlation values show that the relationship between bending strength and bending stiffness is relatively good - a correlation coefficient of 0.8. On the other hand the relationship between bending strength and grading class is not especially good for any grading methods - a correlation coefficient of 0.6. The density had very little effect on the bending strength - a correlation coefficient of less than 0.3.

PAST, PRESENT, AND FUTURE WOOD QUALITY CONSIDERATIONS FOR FINE HARDWOODS OF THE UNITED STATES

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FDC: 815: 176.1: (73)

The parameters that define wood quality for a particular tree species are directly tied to the end use of that species. In the fine hardwood industry, uniformity in color and texture are important wood quality factors.

Much of what is processed by industry depends on the availability of the resource. In the past, large diameter, slowly grown trees harvested from natural stands of timber were the industry standard. In recent years, such trees have become scarce and industry is being forced to harvest smaller diameter, younger trees.

One way to alleviate this problem is to manage our existing resource to encourage faster growth and larger diameters for future crops. Hardwood management is practiced on a very limited scale in the United States. Our research is focused on efforts to learn more about the effect of faster growth rates and shorter harvesting cycles (and consequently more juvenile wood) on the quality of hardwoods. We are also examining how soil and site may affect wood quality. In order to do this research, we are examining properties of wood grown in hardwood plantings and are working with a veneer company to see how soil properties influence heartwood color in naturally grown trees.

Some of our early results indicate that black walnut trees grown at faster rates under managed conditions have acceptable heartwood color. Unfortunately, the trees have a wider sapwood and more knots than more slowly grown trees. In addition, planted white oak trees had acceptable lumber grades for their size and possessed good heartwood color. Their growth rates were not uniform, but this variation could have been alleviated by using proper thinning procedures.

Our future supply of high-quality trees for the fine hardwood industry will depend on timber and site management decisions made today. Otherwise, as has so often happened in the past, other species will be substituted for those traditionally used to produce fine hardwood products.

THE EFFECT OF TYPE OF JOINT AND NUMBER OF PLIES ON THE BENDING STRENGTH OF LAMINATED VENEER LUMBER FROM *PARASERIANTHES FALCATARIA*

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SUMMARY

FDC: 812.71: 824: 832.282: 176.1 *Paraserianthes falcataria*

Paraserianthes falcataria, previously known as *Albizia falcataria* is a fast-growing tree species which can reach a diameter of 80 cm. The wood has an average specific gravity of 0.33, strength class of IV to V and a durability class of IV to V. Experimental Laminated Veneer Lumber (LVL) were made from rotary-cut veneer obtained from 45 cm logs. Thickness of veneer was 3 mm. Eight-ply, 10-ply, and 12-ply, cold pressed LVL samples were constructed using UF adhesive. Three types of veneer joints, i.e., butt joint, scarf joint and finger joint, and no joint as control, were used in LVL construction.

The average veneer density was 0.32 g/cm3, whereas the average LVL density was 0.37 g/cm3. Bending strength (MOR and MOE) was tested edgewise and flatwise. Analysis of variance revealed that type of joint and number of plies had a significant effect on MOR and MOE, both flatwise and edgewise. MOR and MOE increased as the number of plies increased. For flatwise testing, the MOR was 627 to 883 kg/cm2 and MOE was 38853 to 86049 kg/cm2.For edgewise testing, the corresponding values were 712 to 906 kg/cm2 for MOR and 60631 to 78196 kg/cm2 for MOE. MOR and MOE of the solid wood were 526 kg/cm2 and 44500 kg/cm2, respectively.

The use of joints in LVL construction decreased the MOR as well as MOE both flatwise and edgewise, the LVL with scarf joint being the strongest and those with butt joint the weakest.

VOLUNTARY PAPER SUMMARY

LASER SCANNING FOR THE DETECTION OF "TWIST OR WARP" IN PENCIL SLATS

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FDC: 854: 832.182

Pencil stock is made from incense-cedar (Libocedrus decurrens or Heyderia or Calocedrus). The pencil slats are sawn out of blocks 18.4 cm (7 1/4 in) long and 80 mm (3 in) square and they have a thickness of approximately 4.8 mm. The pencil slat is defined as having twist when any one of the two planes of the slat is not parallel to the other. Roughness due to saw marks or height variation between late wood and early wood could not be counted in the definition. A minimum amount of twist, however, also had to be neglected. For instance, cedar slats are pliable and flatten easily under pressure and proper gluing in the production process holds the two slat sandwich together. This is defined as the "threshold of allowable twist," and this had to be adjustable. The objective was to develop a scanner for the detection of true twist or warp in the pencil slat at high speed as opposed to measuring slats which were too thick or too thin. All of the above was accomplished with three lasers. All measurements were done in near real time at a speed of 600 slats/minute. The unit was satisfactorily tested on a laboratory machine at full speed and is presently running on a production machine for full scale testing. The paper will present a pragmatic approach toward the solution of the problem.

WOOD AND COMPUTER INTEGRATED MANUFACTURING : WHAT IS THE FUTURE ?

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FDC: 8: 946.2

A European symposium has been organized by the CTBA in May 90 on the topic "Wood and Computer Integrated Manufacturing : What is the future ?" A special emphasis was given to sensors for non-destructive testing with application to timber grading and manufacturing process optimization (mainly log sawing, edging and cross-cutting). An other session was reserved for CAD / CAM systems, their introduction and future in the wood industry. This paper is an abstract of the main recent development presented during the symposium and conclusions of the participants on the future of Computer Intergrated manufacturing in the Wood industry. It gives the research needs as selected by Wood industry and machine toll manufacturers and the resulting strategy policy coming out as result of the debate.

POSSIBILITIES FOR MANIPULATING LIGNIN CONTENT IN CONIFERS, AND ITS EFFECTS ON WOOD QUALITY

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FDC: 813.11: 161.7: 165.62: 815: 174.7

It is well known that temperate zone conifers have, on average, a significantly higher lignin content than have temperate zone hardwoods. Biochemical research has revealed that xylem development is possible in the complete absence of lignification; however, a wood lacking lignin would have neither compressional strength nor the hydrophobicity required for water flow through the stem. But the fact that hardwoods can produce tall trees and high quality wood, despite their lower lignin content, suggests the lignin content of conifers may be reducible to some degree without adverse effect on wood quality. This possibility has special economic relevance to the pulp and paper industries.

The biochemistry underlying lignification in conifers is examined with respect to the pathways leading to para-hydroxyphenyl and guaiacyl lignins, and the intrinsic regulation of these pathways is briefly considered. Some key enzymes that may be modifed through genetic engineering for reduced lignification are considered.

The lignin content of conifer woods is contrasted with other measures of wood quality. It deserves emphasis that most analytical techniques for estimating lignin content are inconclusive with respect to chemical bonding of lignins with polysaccharides. In other words, a wood may be of high lignin content and yet of low strength, such as is the case with compression wood, or of relatively low lignin content and yet of high strength (e.g. Sitka spruce and larch species). Thus reduction of lignin content probably will not invariably lead to a lower strength wood.

The limited information so far available suggests that during the process of wood formation photosynthate (i.e. sucrose) is partitioned between polysaccharide and lignin through a competitive process. In other words, by reducing the lignin content of conifer woods it can be anticipated that the cellulose and hemicellulose proportions of wood will be elevated.

The role of peroxidase, a key enzyme in lignification, in degrading auxin is also noted. It is suggested that if peroxidase activity were reduced, not only would it result in reduced lignification but also in a more porous stem that increased more rapidly in diameter.

TRENDS IN TECHNOLOGY DEVELOPMENT IN SAWMILLING-AND-WOODWORKING INDUSTRY

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FDC: 822: 832.15

Three specific groups of manufacturing methods could be identified in traditional sawmill practice the world over: the North American, the Scandinavian, and the Central European technologies. The Japanese sawmill technology has certain differences. Nevertheless the considerable differences that had existed earlier among these technologies have been on the decrease in recent times and the production at the more advanced sawmilling enterprises has been acquiring many common features.

It must be noted that in many advanced countries sawmilling is export-oriented. For example, more than 70% of all the lumber produced in Canada goes for export. This indicator for Sweden also reaches 70%. Not less than 50% of all the lumber produced in Finland and Austria is also sent for export. In this case, quite naturally, the lumber represents the final product, is fully processed and has a market-ready appearance.

In the USSR at the present time about 100 million cubic metres of lumber are produced annually out of which only about 8% is exported. This means that the greater part of the lumber produced goes for internal consumption. A considerable fraction of this lumber is processed directly at the site where it was produced.

Obviously the sawmilling technology in this case may have and must have its peculiar features with reference to the totality of operations as well as the equipment used. The sawmilling industry here could be and must be considered only as one sector of a single process of conversion of timber into the final product, not only within the confines of a single enterprise or single amalgamation, but also within a production branch and even within the country as a whole.

The cost of raw materials has always exerted and still exerts the biggest influence on the economics of production of lumber in the sawmilling-and-woodworking industry. The specific weightage of raw material cost in the cost price of sawn timber in different countries, for example, is not less than 60-80% as a rule. In this connection, obviously, a better utilization of wood resources to be processed might be considered as one of the chief directions for perfecting the technology of sawmilling-and-woodworking industry. The processing of wood resources must be considered in its totality, begining from the cross-cutting of tree-lengths and ending the manufacturing of sawntimber blanks and other components.

DEVELOPMENT OF AN OPEN PAN STOVE FOR PALM SUGAR EVAPORATION*

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FDC: 892.68: 831.1: 839.82--015.24

A study was undertaken on the development of an open pan stove for palm sugar evaporation as a means of reducing the farmers' cost of using fuelwood. The stove performance was evaluated in terms of heat utilizaiton efficiency. Combustion tests were conducted with para rubber wood, Hevea brasiliensis which has a higher calorific value of 4,368 kcal/kg.

In this experiment the mean efficiencies of one, two and three open pan stoves at any instantaneous time were 26, 37 and 39 % respectively. A start-up time of approximately 30 minutes was required to bring all the stoves up to steady state and operating conditions. Ash disposal and slagging did not pose a problem.

* A contribution to the Thai French Farming Systems Research Project, Faculty of Natural Resources, Prince of Songkla University, Hat Yai Campus, Thailand

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POTENTIAL IMPACT OF CURRENT WOOD UTILIZATION RESEARCH ON U.S. MARKETS FOR PULPWOOD, SAWTIMBER, LUMBER, AND PANELS

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FDC: 8: 72/73: (73)--01

As part of the USDA Forest Service 1989 Resources Planning Act timber assessment, the potential impacts of seven areas of current Forest Service wood utilization research on U.S. pulpwood, sawtimber, lumber and panel markets (prices, consumption, and total annual consumption value) to the year 2040 were analyzed. The research areas are (1) harvesting, (2) lumber and plywood-veneer processing, (3) expanded use of timber bridges, (4) new or improved wood composite products, (5) engineering of wood structures, (6) adhesives from renewable resources, and (7) pulp, paper, and paperboard (PP&P) processing. Base case market projections were compared with seven altered projections made by the Timber Assessment Market Model.

In terms of potential magnitude of impact, the seven research areas fall into three categories. The first four research areas would each cause less than 5 percent change in price, harvest or consumption, and annual value of pulpwood, sawtimber, lumber, or panels through 2040. Research on engineering of wood structures and development of adhesives from renewable resources would change price or consumption of some products by 5 to 20 percent by 2040. Research on PP&P may decrease softwood pulpwood consumption by 36 percent and increase softwood sawtimber harvest by 17 percent by 2040. The research areas, except for PP&P, are expected in the long term to lead to higher softwood prices and, with the exception of adhesives and PP&P research, to higher softwood sawtimber harvest because of increased demand for softwood products.

Although PP&P research has the potential for causing the greatest long-term change, the effect would not be expected until after 2010. PP&P research would decrease prices, quantity, and value of pulpwood consumed and increase consumption of sawtimber, lumber, and panels. Although the consumption of sawtimber, lumber, and panels would increase, prices would decrease substantially and result in lower annual value of consumption. The main effects of research other than for PP&P would occur before 2010 and would generally increase softwood sawtimber price. The non-PP&P research areas would have varying effects on price and consumption of lumber and panels.

The aggregate annual value of sawtimber, lumber, and panels would increase the most as a result of research on engineering of wood structures, by \$0.6 × 10^9 in 2000 and \$1.9 × 10^9 in 2040. PP&P research would have the opposite effect. Annual pulpwood and sawtimber harvest value would change little by 2000 but would decrease by \$1.6 × 10^9 in 2020 and \$6.4 × 10^9 in 2040.

NEW METHOD FOR DETERMINING MODULUS OF ELASTICITY OF STRUCTURAL LUMBER IN PURE BENDING

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The elastic behavior of lumber in bending is affected by a number of factors. It is often desirable to evaluate these effects under pure bending, a condition which is difficult to achieve experimentally especially for lumber members in structural size. The objective of this study was to develop a method to evaluate modulus of elasticity (MOE) of full length lumber members loaded on edge in pure bending. In the method developed, called constant bending, lumber members are loaded by a couple of moments applied at each end of the member using specially designed levers and a cable. The apparatus is easily adapted in a universal testing machine. To validate the method, a series of 38 by 89 mm White Spruce lumber members of varying grades were instrumented with strain gauges and tested over a 1500 mm span. Analysis of the strain data developed revealed that the apparatus was capable to subject lumber members to pure bending regardless of lumber quality. MOE data obtained from constant bending compared closely with MOE data obtained from standard test methods. However, constant bending offers the advantage of testing the member over a longer length using a simpler procedure and simpler instruments.

DETECTING AND DELINEATION OF DEFECTS IN HARDWOOD LUMBER WITH THE SLOPE-OF-GRAIN INDICATOR

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FDC: 852--01

The Slope-of-Grain Indicator (SGI) is a scanning device that successfully measures localized slope of grain around knots in planed softwood lumber. The SGI may also have potential for scanning in furniture rough mills if it is sensitive to defects in unplaned hardwood lumber. Such scanning capability would allow computer optimization and automation of the dimension parts cut-up process.

This paper reports the results of two studies using the SGI for defect detection in hardwood lumber. The first study determined the potential for the SGI to scan both planed and unplaned hardwood lumber. Knots, simulated splits, holes, and rot were present in this study's specimens. Using a 3/4-inch capacitance scanning head, the SGI scanned unplaned hardwood lumber as accurately as planed hardwood lumber. Knots and included bark were accurately detected. Both holes and splits were easily detected even though no grain deviation was associated with these defects.

The objective of the second study was to develop software to delineate detected defects with rectangles in a sample of hardwood lumber. Sawing solutions could then be applied to this lumber using currently available software. Software was successfully developed to delineate knots, holes, splits, and bark pockets with rectangles. Some difficulty was experienced in detecting splits and smaller defect types. This was due to use of a relatively large diameter capacitance scanning head of 1 3/8 inch. Accurate delineation of defects will apparently require the use of a 3/4-inch scanning head as used in the first study.

THE EFFECT OF COLLECTOR AREA AND SOLAR TRACKING ON THE PERFORMANCE OF A SOLAR TIMBER DRYING KILN

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FDC: 847.277/278

Although solar kiln drying has been under investigation for two decades, there still exists some uncertainty about its cost effectiveness. In this work the effect of collector area to wood volume ratio (collector ratio) and solar tracking on the drying rate was investigated. The data so obtained should serve as a basis for evaluating the cost effectiveness of solar drying.

As no two drying runs would ever experience the same sequence of weather conditions, consecutive test runs in a solar kiln can not be compared. To overcome this problem a selected period of real weather was simulated in a climatic chamber in which a small solar kiln, containing a single piece of wood (500 x 38 x 158 mm), was placed. Using a control logic that would make the best use of the weather conditions, the wood was dried according to a drying schedule based on wood moisture content. This "solar simulation system" was used to quantify the effect of collector ratio and solar tracking on the drying process under summer conditions.

With a fixed collector at an angle with the horizontal of (latitude of the site + 10°) and a collector ratio of 2.4 m^2/m^3, a piece of *Pinus radiata* was dried from 100% to 12% moisture content in 19.1 days at an average kiln temperature of 25.6°C. Increasing the collector ratio to 12.1 m^2/m^3, the average kiln temperature increased to 27.6°C. Drying times over the above moisture content range could be reduced by 21% (from 19.1 days to 15.1 days) by increasing the collector ratio from 2.4 m^2/m^3 to 7.3 m^2/m^3. Further increases in collector ratio had no effect.

In summer the energy collected by a full tracking collector during a day, was only 6% higher than for a horizontal tracking collector, but 75% higher than for a fixed collector. The average kiln temperatures under full tracking was only 1.5°C higher than for a fixed collector in spite of the higher energy input. The effects of season and latitude of the kiln site on solar tracking were investigated and the effect of tracking on drying times are discussed.

Depending on the cost, collectors up to 7 m^2 per m^3 of wood could be installed in a solar kiln. A low-cost horizontal tracking system could be cost effective in the tropics.

PRODUCTION OF DISEASE-RESISTANT HYBRID POPLAR CLONES IN EASTERN ONTARIO--FIRST RESULTS OF ARTIFICIAL SCREENING TRIALS

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Program Forester, Fast Growing Forests Group
Ontario Ministry of Natural Resources, Brockville, Canada

FDC: 165.62: 165.41: 181.51: 443: 176.1 *Populus deltoides* x maximowiczii: 172.8 *Septoria musiva*

Septoria musiva is an endemic pathogen that causes leaf spots and cankers on *Populus* clones. Cankered material has been found to be unsatisfactory as a sole source of pulp fiber.

Although canker incidence was lower in eastern Ontario, a 1984 study found little difference in the morphology and physiology of different isolates of *S. musiva* collected from plantations in the north central United States and those collected in eastern Ontario. By 1987, however, a high incidence of severe cankers in a few plantations was observed. A survey of canker incidence in all plantations (203 ha) of six *P. nigra* x *maximowiczii* (NM) clones was made. Of the total area planted to hybrid poplar (1,450 ha) in eastern Ontario, 11.0% was affected to some degree with Septoria damage; 38.7 ha (2.7%) had a very high incidence of damage. Five of the clones were determined to be too susceptible for further plantation establishment.

Local screening for resistance is the most promising long-term control strategy in areas where *S. musiva* is a problem. To increase the reliability of artificial screening tests, support research is being conducted.

Little is known about the genetic variation in aggressiveness of the fungus throughout its range in northeastern North America. It is important to understand this variation to select meaningful isolates for artificial screening tests. Different levels of aggressiveness were detected for *S. musiva* in field inoculations of four *Populus* clones with seven local canker isolates from eastern Ontario and one from Quebec. The genetic structure and possible biochemical markers for aggressiveness of these isolates, based on isozymes, will be presented.

It is also important to understand the variation in levels of susceptibility to *S. musiva* among *Populus* clones to exploit possibilities for resistance breeding. Thirty randomly-selected individuals in each of two half-sib families of *P. deltoides* x *maximowiczii* were inoculated with one isolate of the fungus. A T-test detected a significant difference in percent infection between families. The genetic structure and variation of individuals within these families was investigated using isozymes. Results from these studies will be presented and possibilities for selection based on biochemical markers for resistance to *S. musiva* will be discussed.

DIFFERENCES IN SEQUOIA SEEDLING STEM ANATOMY IN RESPONSE TO DIFFERENT OZONE FUMIGATIONS

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Laboratory of Tree-Ring Research, University of Arizona, Tucson, USA

FDC: 425.1: 164.4: 161.7: 174.7 Sequoiadendron giganteum Buchh.

Although many ozone fumigation studies indicate a reduction in photosynthetic capacity and increased respiration in foliar tissues exists with increased exposure to the pollutant, few studies have investigated the impact these changes have on the primary and secondary structure of woody plants. The influence of ozone exposure on the development of stem tissues in Giant Sequoia (Sequoiadendron giganteum (Lindl.)Buchh.) seedlings is the focus of this presentation.

Current year germinated Sequoia seedlings were exposed to three different ozone exposures in open topped chambers in the Giant Grove, Sequoia N.P., California, USA during the summer 1988. The three treatments were; carbon filtered air, ambient air and a 50% increase in ozone over ambient air. Overall, stem diameter was significantly reduced in seedlings exposed to the 50% increase in ozone. The reduction in total stem diameter is manifest in reduced thicknesses of the cortex and xylem cylinder. There were no observed reductions in the phloem thickness. The reduction in the diameter of the xylem cylinder is, in part, due to a reduction in the number of secondary tracheids per radial file. Last formed tracheids were significantly larger in radial diameter with thicker cell walls. The number of fibers in the phloem was also reduced.

PRODUCTION CONTROL IN PLANER MILLS

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FDC: 832.1--015.5

Accomplishment of the optimal production system, where materials are processed and transported continuously without delay, is the key to improve productivilities and also to success full automization of the production system. Improvement of the existing production system is undertaken from the fixed operational efficiency either at the first process (input capacity) or the final process of the line (processing capacity). However, the process which causes a bottle neck in the system should be eliminated by replacing or adding it with more effective installation, or by improving its operational function.

The real production system is simplified into a mathematical model and the process of production is reproduced numerically with the lapse of time. The computer simulation to analyze the production system in course of developing now consists of two functions; i.e. 1) based on the probability distribution of service time in each process (time required for waiting to input, processing or transporting materials), random numbers (times) which reproduce service times of the real process are generated artificially by the Monte Carlo method, and 2) material flows through a whole of the production system are reproduced numerically with the aid of the queuing theory in course of production time.

Productivility and time distribution to output final products are resulted from the simulation, by fixing input capacity of the first process, and are compared with the reals. The another simulation, started from the processing capacity of the final process, is proceeded to look up the optimal processing time of machines and transportation velocity from a machine to a machine which are able to satisfy continuous material flows through the production system. Simultaneously recommendable time interval to input raw materials at the first process will be also suggested.

Observation of material flows was undertaken at the planer mill of the Gran Tre company located 300 km northeast of Oslo City, Norway.

This work was made possible by a grant from the Royal Norwegian Council for Scientific and Industrial Research. The author gratefully acknowledges Professor Rolf Birkeland, Director of Norwegian Institute of Wood Technology for allowing him to work there.

PLANNING PROCESSES WITH STOCHASTIC BEHAVIOR

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FDC: 832.1--015.5

The secondary breakdown process of planer-mills shows a certain degree of stochastic behavior. A clean, theoretical model to aid in planning such processes is needed.

Most existing theory on planning concerns converging, deterministic processes where several raw materials are collected into one product. An eventual stochastic behavior is of relatively small impact and can be handled by quality control systems.

The secondary breakdown in planer mills is a diverging process where raw material is split into several of finished products. The process is also stochastic meaning that he exact mix of individual products can not be determined at the planning stage. This kind of behavior is not unique to the sawmilling industry. Diverging processes can be found in several industries ranging from oil refineries to butcheries. What seems to be unique to sawmilling is the degree of uncertainty in the process.

The aim of planning is normally to minimize the total cost of producing a predetermined volume of one product. Minimizing raw-material spending and maximizing value recovery are the main planning criteria. Inventory costs and costs from producing an insufficient volume of the main product must also be taken into consideration in order to avoid overflowing of unsellable products in the inventory.

The process consists of resawing and planing with grading on the output end of both processes. The product mix is an assortment of planed and rough products of various grade. Sawdust, shavings, ribs etc. make up the balance. The volume of by-products is deterministic and can be calculated from the geometric definition of the breakdown process.

The mix of lumber products is stochastic, and a model for predicting the outcome of the process is needed. Samples taken from Norwegian planer-mills will be used in order to find a statistical model suitable for that case. This will be fitted to existing planning models in order to get one step closer to a good theoretical model for planning of the secondary breakdown process.

GLUING OF WOOD BASED PANELS WITH POLYMERIC ISOCYANATE WITH SPECIAL EMPHASIS ON PARTICLEBOARDS.
PROGRESS AND PROBLEMS

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FDC: 824.839: 862.2

Polymeric isocyanate (PMDI) was first used for gluing core layers of particleboards in 1973. Since then PMDI has increasingly been used as binder in numerous laboratory investigations as well as in the industrial production of wood based panels.

The paper reports on the state-of-the-art of, inter alia, PMDI-gluing of plywood, glulam beams, double-T beams, waferboard, strandboard, low-density particleboard and particleboard made from straw. The examples given for the use of PMDI as binder for wood based panels show, on the one hand, good results for particleboard, waferboard and strandboard, while on the other hand it is also demonstrated that a great amount of development work remains to be done. Foremost aim is to make PMDI as universal in applicability as phenolic resin is to-day.

Industrially produced structural particleboard shows lower wet internal bond (2 hours' boiling test) if the core contains beech and oak particles. Wet internal bond of PMDI-bonded panels was vastly improved by mixing hardwood flakes with wool-flakes from aspen.

Microscopic investigations on PMDI distribution on particle surfaces and particle cross sections suggest that PMDI spreads easily, forming very thin layers and is obviously also able to penetrate the woody tissues. This excellent wettability is responsible for the chemical bonding between the NCO-groups and the hydroxyl groups in wood and hence for the good mechanical and physical properties of PMDI-bonded panels. The low wet internal bond properties can be explained by the hydrophobic character of PMDI panels as a consequence of the thorough spreading of glue on the wood particles. Due to the slow water absorption during the 2 hours' cooking test and the resultant uneven stress distribution the internal bond specimens in the core layer are being adversely affected.

STUDY ON THE OXYGEN ALKALI SEMICHEMICAL PULPING OF SOME TAIWAN BAMBOO SPECIES

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FDC: 861.13/.14: 175.2

Soda-Oxygen Process is developed, in the recent years, for the purpose of decreasing the pollutant formed during the pulping process and increasing the pulp yield. In this study, three species of bamboo were selected and two-stage Soda-Oxygen process were used. During the first stage of pulping process, the bamboo chips were cooked with soda to soften the chips then treated mechanically with disc refiner in order to fibrilize the cooked chips. During the second stage, the soda-oxygen was used for the further delignification of the completely fibrilized pulp.

The three bamboo species used in this study were Bambusa Stenostachya, Sinocalamus latiflorous, and Bambusa dolichoclada; which were collected from the Experimental Forest, National Taiwan University. The bamboo chips were cut into nominal size of 3.5 cm in length and 1.5 cm in width, after air drying, the chips were ready for cooking.

From this experiment, the optimum pulping conditions were found as follows:

First Stage: Alkali charge: 10% NaOH (as Na_2O)
Cooking temperature: 120°C
Cooking time: From room temperature to 120°C in 60 min., and at 120°C for 120 min.
Bamboo to liquor ratio: 1:4

Second Stage: Alkali charge: 4% NaOH (as Na_2O)
Cooking temperature: 110°C
Cooking time: From room temperature to 110°C in 45 min., and at 110°C for 10 min.
Pulp consistency: 20%
O_2 Pressure: the higher the O_2 pressure the better in the range that the digester can hold.
$MgCO_3$: 1% (as MgO), but if higher tear factor is desired, a little more $MgCO_3$ can be charged.

According to the results of this experiment, the yield of first stage was 50-53%, Kappa No. was 87-95, the yield of second stage was 40-44%, Kappa No. was 60-65. The Soda-Oxygen process produced no more than 2% yield over that of kraft process. The strength properties of Soda-Oxygen pulps were lower than those of kraft pulps, but the brightness of Soda-Oxygen pulp was much higher than that of kraft pulp.

ON THE FINE STRUCTURE VARIATIONS OF THE IMPORTANT CONIFERS IN TAIWAN

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FDC: 811.1: 174.7: (529)

The ultrafine structure of nine economically important conifers grown in Taiwan were examined with Scanning and Transmitted Electron Microscopies, EDAX (energy dispersive analysis of X-ray) technique was also introduced to explore the constituents of lumen inclusion.

It is surprisingly obvious that pit membrane and lumen contents of tracheid or parenchyma at different heights and radial distances in the same tree vary in its construction and composition respectively, not to mention those in different species. Information was therefore collected from thin sections derived from various spots in the trunk to ensure a complete spectrum of the variation.

Margo and torus were carefully appreciated and categorized. Torus varies mostly in its shape, thickness, number of laminates and degree of electron density under TEM, while margo differs in its thickness and existence of splits among compositive fibril bundles. 3-4 laminates are outstandingly evident in the tracheid tori of _Chamaecyparis_ _formosensis_, _Abies_ _kawakami_, _Cunninghamia_ _konishii_ and _lanceolatea_, and _Cryptomeria_ _japonica_, while those in the other four species demonstrate almost homogeneous electron density in the whole torus showing their similarity in both composition and elemental concentration. The margo of _Cryptomeria_ tracheid splits distinctively at its ends while that of _Taiwania_ shows multilayer structure. Cell dimension and wall thickness of the tracheids in the species studied rank at 30-50 um in width, 3-6 and 10 um thick in double cell wall for early- and latewood respectively.

Crystal or amorphous inclusions are found not only in the lumen of some parenchyma but also of tracheid. Calcium, silicon, aluminium and sulfur are the four main elements most frequently encountered in the lumen inclusions. The percentage of constituents differs among species.

Poster Abstracts
Résumés d'affiches
Kurzreferate füt Postersitzungen
Descripción resumida de posters

Poster abstracts have been arranged in alphabetical order of authors' names.
Les résumés d'affiches ont été disposés par ordre alphabétique des noms d'auteurs.
Die Kurzreferate für Postersitzungen sind in alphabetischer Reihenfolge der Autoren aufgeführt.
Descripción resumida de posters dispuestos por orden alfabético de los nombres de los autores.

501 SMALL SCALE FLUIDIZED BED CARBONIZATION SYSTEM WITH TOWN WASTE WOODY MATERIAL

K Akizuki (Managing Director of Japan Biocarbon Co., Jikkoku, Ami, Inashiki, Ibaraki, Japan), S Kishimoto (Dr of Forestry, Adviser of Japan Fuel Association, Mitaka, Tokyo, Japan), S Satonaka (Dr of Forestry, Forest Products Scientist, Sapporo, Japan)

A practical fluidized bed carbonizer has been operating since March 1988 at Ami, Japan. Raw material is mainly destructed houses which previously had no commercial use.

The material is broken to small particles (length 6 mm, dia 2 mm) in two steps. Iron such as nails are separated by magnetic equipment between the two steps. The particles are dried to 15 % moisture content and the micro dust is also separated. The prepared particles are screwed into a vertical fluidized bed carbonizer with dimensions of 1,5 m diameter and 4,5 m high. The temperature of the carbonizer is controlled at 400 to 500 °C by the velocity of screw feeder. The production capacity is 450 kg of dried charcoal per 1 hour.

The charcoal is sprayed with some water and is packed in a 401 bag. The weight of which is 13 kg including 40 % moisture content. The charcoal has 15 to 20 % volatile matter. Needed raw material is approxiately 2000 kg/hour. Therefore, the charcoal yield is ca. 26 %. The required quantity of woody waste per day is abut 53 ton in case of 24 hour operation.

The produced charcoal is used as a soil reformer which increases the penetrability of air and water. This results in the acceleration of growth and in higher yields of agricultural products. This charcoal is used for the culture of fruit-melon and strawberry, etc. But these results are not dealt with this time.

The investment for the mechanical apparatus is about US$2,1 million which equals to Y300 million. This fluidized bed carbonization system is considered a stable process, especially since the plate pore structure is improved in the carbonizer. This system is not accompanied by pollution. The further utilization of recovered heat is now under planning.

502 A FUTURE COMPUTER VISION SYSTEM TO GRADE AND DESCRIBE HARDWOOD LUMBER

Araman P., Project Leader, USDA Forest Service, and Conners, R., Assoc. Professor, Virginia Tech University, Blacksburg, Virginia, USA

A computer vision system that is being developed by a team of researchers in several locations will be presented. The system is being developed to recognize board defects, clear wood, and board outlines of rough hardwood lumber and to label and define these areas. This information would then be fed into two computer programs. The first program would grade the board by National Hardwood Lumber Association grading rules. The second program would simulate the processing of the board into standard or customized cutting or part sizes by two different cut-up methods. The first method would be to cross cut the board first and then rip the the cross cut pieces into cuttings or parts. In the second method this process would be reversed. The system output would include information on individual boards and for packs of lumber. A pre-prototype vision system will be shown and described. Defect recognition slides will also be shown.

503 RESEARCH TO IMPROVE THE MARKETABILITY OF HARDWOOD LUMBER

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24061-0503 USA

Based on the desire to improve the marketability of hardwood lumber, research is being conducted to computer vision grade hardwood lumber under National Hardwood Lumber Association rules. This will include grade stamping on the graded lumber and bar coding. Also included will be descriptive data on each board describing the cuttings available in the board and whether it would be better to rip or cross-cut the board as the first step in processing the board into parts. Summary information for packs of lumber will also be generated for marketing purposes. In this presentation, we will get a progress report on the computer vision research and the complete package of programs needed for implementation.

504 Classification of log based on sound analysis and its application for grading laminae and drying process control

Arima, T. , and Nakamura N. (Faculty of Agriculture, Tokyo University, Tokyo, Japan), Hayamura S. and Maruyama N. (Faculty of Agriculture, Shizuoka University, Shizuoka, Japan)

The modulus of elasticity (Et) of log was determined by measuring the natural frequency of longitudinal wave due to sound when hitting cross section. The Et of laminae and post-sized lumber with pith produced by the log were also measured. Results were as follows:

(1) Et was recognized to be highly linear to the modulus of elasticity due to static bending test (Es).

(2) Since the Et of post-sized lumber and the average value of Et of laminae was recognized to be highly linear to Et of the original log, this rough classification of log could be useful in the selection of raw materials for structural lumber and glue-laminated lumber.

(3) Since changing of natural frequency during drying process was affected by the increase of Et and weight loss due to desorption of water, it might be effective as rough quality control of drying within a well-known increase of Et.

(4) The third-term natural frequency of longitudinal wave was hardly affected by piling in stock yard as compared to the first or second ones, thus longitudinal wave sound analysis could be considered as a reasonable material selection and control system.

505 A STUDY OF AN UPDRAFT WOOD GASIFIER

W Arunlaksadamrong and D Khummongkol (Department of Chemical Engineering, King Mongkut's Institute of Technology Thonburi, Bangkok 10140, Thailand

The effect of wood size and air flow rate on the performance of an updraft gasifier was investigated. The wood used in this study was obtained from mangrove trees; it had a diameter of 5 cm and a length varying from 2 cm to 5 cm, and the air was induced into the gasifier at the rate of 0,37 to 0,58 kg/min. The experimental results indicated that both wood size and air flow rate affected the temperature distribution in the gasifier. The concentration of carbon monoxide greater than 28,7 % was estimated to be achievable at the wood size of 2 to 3 cm and the air flow rate of 0,44 to 0,51 kg/min.

506 CLASSIFIED USES FOR WOOD PRODUCTS IN HONDURAS

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National Center for Applied Forest Research (CENIFA)
Siguatepeque, Honduras

This work deals with the classification in 15 groups and 60 subgroups of the forest products according to their characteristics and practical applications. The classification aims to establish a reference framework for the different products of the secondary forest industries of Honduras. A diversified secondary wood industry would improve the utilization standards of the available resource, and promote the gradual substitution of more traditional and scarcer tropical forest species, for less known ones with similar properties.

The study recommends to increase the use of non-traditional forest species, to improve conversion efficiency, and to incorporate the logging activity into a more global management plan for the tropical forests.

507 **Multivariate Analysis of Business Strategy in Wood-Based Primary Industries.** Bush, R.J. (Department of Wood Science and Forest Products, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0503). Identification of the competitive strategies utilized by companies within an industry can provide valuable insight into industry structure and evolution. Unfortunately, competitive strategy has proven to be a difficult concept to quantify in a reliable and valid manner. Much of the research concerning competitive strategy has focused on large corporations (corporate-level) and may not be applicable at the business-level or to the highly fragmented environments in which many North American wood-based industries operate. As a result, a methodology for assessing business-level competitive strategy and strategic change at the business-level was developed. A multiple item measure that utilized Porter's (1980) three generic strategies (*Overall Cost Leadership, Focus, and Differentiation*) as dimensions of overall strategy was adapted from the work of Dess and Davis (1984). Factor analysis was used to confirm the dimensionality of the measure and to develop factor scores. Cluster analysis of factor scores was used to place companies into strategic groups that were relatively homogeneous on the three strategic dimensions.

The methodology was used to investigate strategic groups and strategic change in the U.S. hardwood lumber industry. Data were provided by 72 of the largest hardwood lumber producers. Five strategic groups were identified. The largest portion of strategic variation was attributable to the *Overall Cost Leadership* and *Differentiation* dimensions. Larger companies (as measured by hardwood production) and those that sold a large portion of their output kiln-dried were most likely to emphasize aspects of differentiation.

In addition to their present emphasis on various aspects of competition, the companies indicated the aspects they planed to emphasize in the near future (next five years). Multivariate analysis of this data was used to predict strategic change in the industry. Predicted strategic change was, primarily, in the direction of increasing emphasis on differentiation. All groups showed significant movement, at least in part, in this direction.

508 **A WOOD DRYING MODEL USING THE GRADIENT IN WATER POTENTIAL AS THE DRIVING FORCE OF MOISTURE MOVEMENT IN WOOD**

Cloutier, A., Fortin, Y., Dhatt, G. (Graduate Student and Associate Professor, Département des sciences du bois and Professor, Département de génie civil, Université Laval, Sainte-Foy, Québec, Canada, G1K 7P4)

During the last 65 years, a great deal of research has been done in order to improve the understanding of the mechanisms causing the movement of moisture within wood during drying. The development of computerized kiln controllers enhanced even more the interest for reliable predictive models of moisture movement in wood. In the present study, a two-dimensional model of drying in isothermal conditions is proposed. The model is based on a diffusion-type equation using the gradient in water potential as the driving force. The study is divided in three steps: 1) evaluation of the moisture content-water potential relationship at 20, 35 and 50°C, 2) evaluation of the hydraulic conductivity-moisture content relationship in the radial and tangential directions at 20, 35 and 50°C, and 3) resolution of the model by the finite element method and comparison of the solutions with the moisture content profiles obtained during actual drying of wood. The results show that: 1) both the moisture content-water potential and the hydraulic conductivity-moisture content relationships are affected by temperature, 2) the hydraulic conductivity in the tangential direction is significantly lower than in the radial direction, and 3) a good agreement is found between the solutions obtained with the model and the moisture content profiles obtained during actual drying of wood.

509 STUDY OF USING VENEER AND PLYWOOD WASTES IN PARTICLEBOARD MANUFACTURING.

K. Doosthoseini and M. Kashanizadah, Faculty of Natural Resources, Karaj, Iran.

The main purpose of this study was whether it was possible to make particleboard out of veneer and plywood's wastes. Results indicated that the boards made of the thinner chips and higher slenderness and contact area ratio had better bending properties and higher density. The water absorption and thickness swelling of such boards were low. By increasing mat moisture content up to 14 percent, the bending properties, internal bond and dimensional stability improved. Increasing the press temperature up to 175 degree Celsius would cause the mechanical properties and density of the boards to be improved. The longer the press time specially accompanying the lower press temperature, the better board characteristics would result. The final determination of the study indicated that the best veneer wastes/low wood ratio was the one used 25 percent veneer and plywood's wastes.

510 **Market trends and prospects for dissolving wood pulp. Durbak, I. (USDA Forest Service, Forest Products Laboratory, Madison, WI 53705-2398, U.S.A.)** According to results of a recent study, production and consumption of dissolving wood pulp declined during the 1970s and early 1980s, both in the United States and worldwide. In recent years, however, overall trends and growth in some world markets have remained constant.

A major use for dissolving wood pulp is in the manufacture of cellulosic fibers—rayon and acetate. These fibers are used for textile fabrics and for various medical and industrial products, including tire cord. Acetate is also used for cigarette filters. Rayon and acetate fibers constitute less than 10 percent of all manufactured fibers produced and consumed worldwide. The market for rayon and acetate has been relatively stable considering the continued dominance of cotton and the sharp increase in production of synthetic fibers.

The study compiled and analyzed data on production, consumption, and trade of dissolving wood pulp and the cellulosic fibers—rayon and acetate—produced from it. Data on production and use of competing natural and synthetic fibers, such as cotton, silk, nylon, and polyester, were also analyzed. Results describe trends in world markets and in major end uses, with special emphasis on the manufacture and use of textile fibers in the United States. This poster session presents an overview of the industry worldwide and a summary of trends in end-use markets in the United States.

511 A COMPUTERISED SYSTEM FOR WOOD IDENTIFICATION AND FEATURE IMAGE DISPLAY.

Cheng Fang, Research Institute of Wood Industry, Chinese Academy of Forestry, Wan Shou Shan, Beijing, P.R. of China.

A computerised system WIP (Wood Identification Program) for wood identification, species index, and image display of wood anatomical features has been developed. For 669 woody species, mostly Chinese, including 500 hardwoods and 169 softwoods, wood anatomical data have been stored. In addition, 27 images covering 50 anatomical features can be retrieved for identification and display.

The system uses a SUN 386-24 microcomputer with 2M byte RAM, 40M byte fixed disk, and EGA graphics adaptor. The software of the system consists of a main program (WIP), and several utility programs for maintaining and creating databases. All the programmes are written in Turbo Pascal 4.0, which could be run on all of the IBM PC compatibe computers. The menu driven system is user-friendly and searching time is minimal (c. one second).

512 COMPLEX WOOD PROTECTION BY MEANS OF COMPOUNDS ON THE BASES OF TRICHLORETHYLPHOSPHATE.

A. S., Freidin, G. N. Myshelova, E. N. Pokrovskaya, Central Scientific Research Institute for Building Structures, Moscow, USSR.

For complex wood protection against biodamages and ignition, various modifications of solutions and aqueous emulsion on the basis of trichlorethylphosphate (TCEP) are worked out in the USSR.

TCEP is ester of orthophosphoric acid and ethylene chlorhydrine, a large-capacity product of Soviet chemical industry.

Composition of fire- and bioprotective effect doesn't conceal wood texture, even surface application with consumption of 600 g/m^2 ensures high level of wood fire protection.

Tests on methods of building code and regulations 2.0I.02.85 "Fire prevention measures", held on fire surface spreading indicates high fire protective effects.

Results of fire resistance tests allow to place protected wood to group of difficult combustion materials.

High bioprotective effect is achieved with consumption of 200 g/m^2.

Protective treatment with worked out compound can be carried out by means of traditional methods of surface application or impregnation.

513 MODIFIED RESORCINOL RESIN ADHESIVES FOR TIMBER AND WOOD BOARDS.

A. S. Freidin, M. G. Malyarik, A. E. Grib, G. M. Klausner. Moscow, USSR.

Field of application of high-quality resorcinol and phenol-resorcinol adhesives for load-carrying and wall structures made of wood and plywood is limited by small raw materials base of resorcinol and by great internal stresses. Cutting of adhesive costs and expansion of their raw materials base is ensured by the use of alkyl-resorcinols from processing products of Estonian oil combustible shales. Adhesives of this type are widely used in load-carrying and wall structures made of wood and wood materials for construction public and agricultural engineering.

Considerable reduction of internal stresses and increasing of durability of structures made of heterogeneous materials with simultaneous cutting of costs, is achieved by means of modification of phenol-resorcinol, alkyl-resorcinol and phenol-alkyl-resorcinol adhesives with liquid elastomers, such as polysulphide rubbers and latexes of some synthetic rubbers.

High use efficiency of such adhesives is shown for connection of heterogeneous materials (wood, metals, wood boards) in wood load-carrying structures joints with glued-in steel bars, for glueing of sheathing made of chip wood boards, plywood, etc. to frame of structures made of wood, cement wood boards, etc.

514 PROPERTIES OF FLAKEBOARD BONDED WITH FILLED AND EXTENDED PHENOL-FORMALDEHYDE RESIN.

Douglas J. Gardner, Assistant Professor, Wood Science, Division of Forestry, West Virginia University, 206 Percival Hall, P.O. Box 6125, Morgantown, WV 26506-6125.

Flakeboard was adhesive bonded with phenol-formaldehyde resin alone and in combination with either clay or pecan shell flour filler or wheat flour extended to assess the effect of filled and extended phenol-formaldehyde resin-adhesives on panel properties. Physical and mechanical properties of flakeboard made from a mixed hardwood/softwood furnish were determined by internal bond, static bending measurements, and a 24-hour test for thickness swell and water absorption. Filled or extended phenol-formaldehyde resin-adhesives result in improved flakeboard physical and mechanical properties. The contribution of fillers and extenders to flakeboard properties may be related to the improved mechanical characteristics of the cured resin-adhesive bond with the wood.

515 MAXIMIZE WOOD FLAKE RECOVERY

Ray W. Garnett, Marketing Manager & Panelboard Product Manager

The average OSB or Waferboard Mill spends over 30% of operating costs on wood fibre supply. It is therefore very important to the economics of these mills to properly tune their flaking machines for maximum quality flake or strand, with minimum fines.

The disc flaking machine has many advantages in the principle of flaking and with photographic diagrams and text, the presentation will demonstrate how you can tune your machine to eliminate curly flakes, minimize production of fines and maximize high quality strand or flake for the most economic production of panelboard.

516 ETUDE TECHNOLOGIQUE DU BOIS DE *Pinus caribaea* Var. *hondurensis* ET DE *Pinus oocarpa* (REGION CENTRE-OUEST DU BRESIL)

J.C. Gonçalez
Professeur à l'Université de Brasilia (UnB)
Génie forestier - Brésil
Etudiant en Doctorat à l'ENGREF-Nancy-France
M.G. Mesquita - G.B. Jünior
Etudiants de graduation-UnB-Génie forestier

Ce travail a été réalisé dans le Laboratoire de produits forestiers (L.P.F)/IBAMA, Brasilia-DF-Brésil. Il a eu pour objectif principal d'étudier les propriétés technologiques du bois de *Pinus caribaea* var. *hondurensis* et de *Pinus oocarpa* à 12 ans, afin de définir leurs utilisations. Le travail a été sollicité par l'entreprise PROFLORA S/A, qui reboise avec ces espèces.

Les études concernant l'anatomie, les propriétés physiques et mécaniques ainsi que le comportement du bois au séchage artificiel ont été effectuées sur 10 arbres de chaque espèce. Pour ce travail, les normes proposées par la Commission Panaméricaine de Normes Techniques (COPANT) ont été respectées.

Les résultats indiquent que les bois étudiés montrent des caractéristiques identiques à celles des bois de conifères tropicaux. En effet, ces bois peuvent être utilisés dans la fabrication de pâte à papier, de panneaux, d'emballages, ainsi que dans l'industrie du meuble, actuellement en expansion au Brésil avec ce type de matière première. Il serait désormais nécessaire d'étudier les propriétés résinifères de ces deux espèces car ces bois ont présenté une forte teneur en résine.

517 ANATOMICAL AND TECHNOLOGICAL PROPERTIES OF THE WOOD OF SELECTED POPLAR CLONES OF DIFFERENT AGES.

Gruss, K. (Institut f. Forstbenutzung, Göttingen, FRG).

Wood anatomical and technological properties were studied of poplar clones Muhle-Larsen (ML), Androscoggin (AG) and Oxford (Ox), (resp. Scott Pauley, 1st trial) in order to obtain data for optimal rotation period and suitability for pulp production. 15 trees of two age groups (5-10 and 15-20 years) were tested. In many properties there were significant differences between closes. In young trees volume was highest in ML and SP (0.0289 m^3 per tree). Branch diameter, branch angle, heartwood/sapwood ratio and bark thickness were generally unfavourable for SP. In older trees ML showed the highest volume production (0.80 m^3 per tree); Ox the lowest (0.58 m^3). ML scored best for other morphological properties in older trees. In young trees SP had the highest specific gravity (0.43 g/cm^3), followed by ML with 0.37 g/cm^3. In older trees spec. grav. ranged between 0.42 (AG) and 0.46 (Ox). Compression wood percentage was highest in young trees of ML (20.2%). In older trees this increased up to 28.2% in ML and 25.7% in AG. Tissue proportions were nearly identical in all clones: 60% fibres; 25% vessels; 15% ray tissue. Fibre length in older trees was significantly higher than in young trees: 0.93 mm (ML); 0.90 mm (AG) and 0.88 mm (Ox).

518 PRODUCTION OF NAVAL STORES IN TURKEY

Harzemsah Hafizoglu, Associate Professor, Department of Wood Preservation Technology, Black Sea University, Trabzon, Turkey.

History of naval stores production in Turkey dates back to ancient times. But a planned production of gum naval stores was started in 1959 on Pinus brutia in Aegean and Mediterranean districts by the General Forest directorate. Although actual capacity of the forests reserved for tapping was 9 352 tons, maximum production was only 6 645 tons/year. Oleoresin produced in Turkey contains 15-25% of turpentine and 70-75% of colophony. α-Pinene is the dominant component in the turpentine. β-Pinene and Δ^3-carene are also significant constituents. Only one plant with a capacity of 3 000 tons/year produces wood naval stores. Sulphate naval stores are recovered in three pulp and paper mills with total tall oil capacity of 22 800 tons/year. Turkish tall oil is distinguished with its high resin and low fatty acid contents. It yields more resin acid fractions with low proportions of impurities in distillation.

519 AN AUTOMATIC CONTOUR TRACKING SYSTEM FOR ROBOTISED SANDING OF FURNITURE WOODPARTS

Han, W., and Thomessen, T. Ph.D. Candidates, Divi. of Production Engineering, Norwegian Institute of Technology, Norway

Sanding of woodparts is a heavily time-consuming task in furniture manufacture. Its automation is desired from the view of both reducing production cost and improving working conditions of the operators. Robotisation is one of the meanses to do so. However, the requirements on flexibility and programming convenience of the robot system is difficult to be satisfied. The automatic tracking system introduced in this presentation is a force-control based system. It possesses high flexibility of sanding a variety of forms of woodparts, especially laminated woodparts. The system also provides possiblity to sand solid woodparts with sanding pressure on-line regulated with respect to grain orientation. With this system, robot programming theoretically takes no more than half a minute, in sharp contrast to one week with teach-in programming implemented in some earlier researches.

520 THE VARIATION OF THE BASIC DENSITY WITHIN THE JUVENILE WOOD OF SITKA SPRUCE (*Picea sitchensis*).

Harvald, C. (Royal Veterinary and Agricultural University, Faculty of Forestry, DK-1871 Frederiksberg C, Denmark).

The variation in the basic-density level of 71 stems of Sitka spruce from three Danish sites has been examined. It is shown that the basic-density level, i.e. the basic density as a function of ring width, within the juvenile wood decreases with (1) increasing distance from the pith and (2) increasing height in the stem (same ring number from pith provided). Furthermore, the basic-density level decreases with increasing stand quality class, which may affect the pattern of variation in basic-density level if the stand quality class varies with age. The basic-density level of the juvenile wood is markedly higher in Sitka spruce than in Norway spruce, which among other things leads to a higher bending strength of planks consisting of a large proportion of juvenile wood (planks originating from fast grown, short rotation trees).

521 INCISING OF WOOD WITH A MULTIKILOWATT CO_2 LASER

Hattori, N., Kitayama, S. (Associate Prof. and Prof. Tokyo Noko University) and Noguchi, M. (Prof. Kyoto University)

Air-dried thin boards(100mm height) of sugi(*Cryptomeria japonica* D. Don) and hemlock(*Tsuga heterophylla* Sarg.) were drilled by the Toshiba 1.2kW and 5kW CO_2 laser changing the irradiated conditions such as the energy of a pulsed laser light, the peak power, the focal length of the lens and so on. The 1.2kW laser is the fast axial flow type and can emit an enhanced pulse and a normal pulse. The 5kW laser is the transverse gas flow type and can emit only a normal pulse using a chopper. Soft X-ray photographs of the drilled thin boards were taken to evaluate the depth and the diameter of the holes. Some 100 × 100 × 400mm blocks of the same species of which all surfaces were sealed with the epoxy resin adhesive were incised under a good irradiating condition of the laser. These blocks were pressure-processed with 3% solution of borax and boric acid. A preliminary vacuum(600mmHg) was applied for 30min followed by the pressure(10° C, final pressure: 15kgf/mm^2) for 1h and the final vacuum for 5min. The preservative penetration in the three sections of the block was measured after the color identification test defined by the Japanese Agricultural Standards. The depth of a hole was affected considerably by the type of the oscillator, the energy of a pulse and the focal length of a lens. The average penetration along the grain was about 65mm for hemlock and about 100mm for sugi while the penetration across the grain was limited to 4mm for hemlock and 5mm for sugi on each side of the hole, respectively.

522 VISUALIZATION OF TEMPERATURE DISTRIBUTION NEAR THE CUTTING EDGE BY MEANS OF A VACUUM DEPOSITION OF THERMOSCOPIC FILM ON MATCHING SURFACE OF A SPLIT TOOL

Hayashi, K.(Forest Resources, Faculty of Agriculture, Ehime University, Matsuyama, 790, Japan) and Tsutsumi, S.(Forest Products,Faculty of Agriculture, Nagoya University, Nagoya, 464, Japan)

To understand a cutting mechanism, as well as to increase the tool life and stability of a saw, it is very important to know the temperature distribution and maximum temperature near the cutting edge. A new method for the detailed measurement of the temperature distribution near the cutting edge is proposed, and an example of it is shown.

The principle of this method is to apply a vacuum-deposited film of various material as the thermo-sensor. The deposited film is formed on a matching surface of a split tool which is assembled to consract a cutting tool. The deposited film is so thin and uniform as to melt without any disturbances at the instant when it reaches the melting temperature. Therefore, the front of the molten region, which becomes an isotherm in itself, is very sharp and obvious.

Each isotherm seems to be very fine circular arc and gives us detailed information of the two dimensional temperature distribution near the cutting tool edge. The face and the flank has steep temperature gradients near the cutting edge.

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PRACTICAL USES OF WOOD RESIDUES

Frederick R. Hose, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa.

Wood residues have become a useful but expensive resource. Nevertheless, a number of profitable products can be made from materials which were previously known as wastes.

Useful products from wood residues include solid fuels, building materials, animal feeds and a variety of chemicals.

To be able to make and use the above products a number of processes or equipment is needed. The latest domestic stoves and industrial combustors are fuel efficient, clean burning and easy to operate.

The use of wood residues in direct form or after upgrading are being investigated by the above institute.

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EFFECTS OF RESIN ADHESIVES ON CREEP PROPERTIES OF WOOD COMPOSITES

Chung-Y. Hse (Principal Wood Scientist, Southern Forest Experiment Station, USDA Forest Service) and R. C. Tang (Professor, Auburn University)

Flexural creep behavior of randomly oriented structural flakeboards under cyclic humidity is presented. Specimens fabricated with six resin adhesives (i.e. phenolic, isocyanate, melamine urea formaldehyde (MUF), phenolic/isocyanate, phenolic/MUF, and isocyanate/MUF at two resin content level (i.e. high and low) were subjected to constant concentrated load in bending under 3-days cyclic relative humidity between 65% and 95% for 60 days. The temperature was set at a constant 75 °F through the test duration and each humidity level. Preliminary results on boards made with phenolic resins showed better creep resistance than those made of isocyanate. Significant improvement on the creep resistance under highly humid environments was observed when the resin content increased. Large deflections occurred and large permanent deformations remained after the relaxation. Creep moduli and relative creep, often considered to be the indices of the long-term performance of flakeboards, were significantly influenced by resin adhesives and by the change of relative humidity. The resulting information may provide a better understanding of the long-term engineering performance of structural flakeboards as affected by resin adhesives and the changes of relative humidity conditions.

525 SPACIAL FIBER ORIENTATION AND SHAPE-OPTIMAL DESIGN: MOLDED WOOD-BASED COMPOSITES OF THE FUTURE?

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In most engineering applications, load-bearing members must counter complex spacial distributions of internal stress. This applies to structural members in buildings, automobiles, and aircraft alike. Metallic alloys and most existing fiber composites are, however, homogenous or have uniform properties in each of their spacial dimensions. It will be argued here, however, that great potential may exist in pursuing technologies which enable complete control of fiber distribution and orientation in the free spacial axis to be achieved. In this way, the spacial distribution of properties may be tailored to the distribution of stresses anticipated on the molded components while in service. Interactions between shape, internal property distribution, and function may then be addressed. This strategy will be developed here with emphasis on the use of wood fiber. The extension of an existing modeling concept (currently used to simulate hot pressing of wood fiber composites) to aid in the development of such new generic wood-based composites will be considered.

526 Current International Trade of Forest Products in Taiwan.

I-an Jen (Taiwan Forestry Research Institute, Taipei,Taiwan)
International trade of forest products has been increased significantly over the past five years in Taiwan. It increased from US$ 1.9 billion in 1984 to US$ 3.3 billion in 1988, with an average growth rate of 11% per annum. But percentage of value of international trade of forest products to total value of the trade declined significantly reaching 3% to 4%. In order words, comparing with other export industry, forest products industry is not so important as before. In 1988, wooden furniture exports decreased 5% from one year eariler, while plywood exports increased 3% during the same period. Softwood logs imports increased 18 times from 1984 to 1988, reaching US$ 27 million in 1988. Softwood lumber imports increased 10 times during the same period reaching US$ 15 million in 1988. Hardwood logs imports increased only 17% during the same period reaching US$ 440 million in 1988, while hardwood lumber imports increased 128% during the same period reaching US$ 254 million in 1988. Particleboard including MDF imports increased 4 times during the same period reaching US$ 27 million in 1988.The booming wooden furniture made hardwood lumber and particleboard imports increase mainly over the past several years. Nowadays, the changing situation of furniture industry make future international trade of forest products more uncertain in Taiwan.

But due to restriction of local timber harvest, reducing export of Southsea area timber, it appears apparent that American timber is going to more important in this market.

527 CAUSE AND EFFECT OF VERTICAL DENSITY GRADIENT IN PF-MDF

Zhang Hong Jian, Department of Forest Industry, Southwest Forestry College, Kunming, Yunnan, China and Zhao Li, Department of Forest Industry, Beijing Forestry University, Beijing, China

In order to explore the potential basis of some optimum parameters in the processing of PF-MDF (Medium Density Fiberboard bonded with Phenol Formaldehyde Resin), the influence of VDG (Vertical Density Gradient) on the common PMB (Physical and Mechanical Behaviours) of the board should be taken into account in the view of technical control.

The conclusions drawn from this research point out that the different PF-MDF for different usages with different expected PMB and VDG can be made by reasonable adjusting the main processing parameters in which moisture content of the mat and the conditions in the early period of hot pressing play a great role; and among the three typical types of VDG named sloping, smooth and sloping-smooth respectively, the sloping-smooth one may be the most ideal VDG, for the board owning this kind of VDG possesses the higher lowest density of core and highest density of top and bottom surface, the higher modulus of rupture and internal bond strength, the lower water absorption, thickness swelling and linear expansion, but the lowest average density which means the lowest cost.

528 The development of marketing strategies of Finnish forest industries during the 1980's

Juslin, H. & Larronmaa, A. & Niemelä, J. (Dept. of Forest Products Marketing, Faculty of Agriculture and Forestry, University of Helsinki, Finland.

The aims of the study are both theoretical and empirical. Increasing the clarity of and the possibility to measure the concept of marketing strategy is the theoretical aim. Descriptions of the strategies and analyses of their rationality and changes during the 1980's are the empirical aims of the study.

The empirical data deals with the Finnish sawmill, wood-based panel, and paper and paperboard sectors. The companies were interviewed both in the beginning and at the end of the decade.

The comparisons of strategies by sectors and branches showed clear differences. In the beginning of the 1980's sawmills were characterized by a lack of selectivity in decisions concerning products, market areas and customers. Commodity product strategy was most common. Panel and paper sectors had more advanced strategies. The whole forest industry advanced it's marketing strategies during the 1980's. The changes were most prominent in sawmill industry.

529 WOOD DRYING PRACTICES IN THE FOREST PRODUCTS INDUSTRY IN INDONESIA

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This paper describes drying practices as the results of a 1989 wood industry survey in Indonesia. The results indicate that industry mainly depends upon air drying and conventional kiln drying without application of intermediate drying processes. From the survey it is also found that drying facilities vary among the industries depend upon the size of operations.

Wood drying technology as practiced by big industry, especially for drying sawn timber for export is based primarily on the technology sold by supplier or producer of dry kiln mostly from Europe. The existing drying facilities consist mostly conventional steam heated kiln with semi or full automatic control system. There is also common method of remote sensing of moisture contents by use of electrodes embedded in drying samples in the kiln.

For small operations the drying technology is more simple, because most of them can not afford to purchase modern kiln. Dehumidification kiln is also commonly used for drying lumber for furniture. For very small operations especially in remote areas in Java, there is a trend of using direct fired kiln for drying jeungjing wood (Paraserianthes falcataria, formerly Albizia falcataria).

530 IMPROVEMENT OF PHYSICAL AND BIOLOGICAL PROPERTIES OF PARTICLEBOARDS BY IMPREGNATION WITH PHENOLIC RESIN.

Kajita, H.*, and Imamura, Y.** (*Department of Forestry, Kyoto Prefectural Univ., Sakyo-ku, Kyoto 606, **Wood Research Institute, Kyoto Univ., Uji, Kyoto 611, Japan)

Particleboards were treated with a low molecular-weight phenolic resin and their enhanced properties were evaluated. Beside dipping of particles in aqueous solutions of the resin and spraying of the resin solutions before spray of the conventional phenolic resin for adhesives, one step treatment by spraying of the mixture of impregnating and bonding resins was also employed. Mechanical properties and dimensional stability of phenolic-resin-treated boards were affected considerably by the weight gain (WG) due to uptake of impregnated resin-solid,however they were not different significantly between the methods of treatment. After 2-hours boiling, the boards treated at 10 % WG retained 80 % of their strength values in a dry condition. The internal bond strength increased with increasing WGs, and the boards of 20 % WG showed twice of the value of untreated controls in the same level of board density. Treated particleboards resulted in a more dramatic reduction in the rate of swelling even though at low resin loadings. Results obtained from accelerated laboratory tests on biodegradation suggested that impregnated resin-solid works well to enhance decay and termite resistance of particleboards. For a brown-rot fungus, the weight loss reached almost nil at more than 15% resin loading, whereas attack was almost suppressed at low resin loadings for a white-rot fungus.

531 INVERSE PHASE GAS CHROMATOGRAPHIC CHARACTERIZATION OF CHEMICALLY MODIFIED FIBERS FOR COMPOSITES.

D.P. KAMDEM and B. RIEDL, Wood Science Department and Centre de Recherches en Sciences et Ingénierie des Macromolécules, Université Laval, Sainte-Foy (Québec), CANADA G1K 7P4.

Inverse phase gas chromatography (IPGC) was used to characterize wood fiber surfaces modified by polymer grafting. From the retention times at infinite dilution over a range of temperatures, the differential heat of absorption, $\Delta\bar{H}_a^\circ$, the standard free energy of absorption, $\Delta\bar{G}_a^\circ$, and the standard entropy of absorption, $\Delta\bar{S}_a^\circ$, have been determined for the n-alkanes vapors (C_8-C_{11}) on wood fibers grafted with poly(methyl methacrylate) (PMMA) at various polymer loadings (PL). The dispersive component of the surface free energy γ_s^L (London) has also been calculated by using a method based on the free energy increment per CH_2 group. Comparison of results for the original wood fiber and PMMA with those of the grafted fibers has allowed the evaluation of surface modification in a thermodynamic fashion.

532 THE INFLUENCE OF SPACING ON THE ANATOMICAL PROPERTIES AND SPECIFIC GRAVITY OF THE WOOD OF POPULUS CLONE

Walid A. Kasir
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The Populus clone examined in this study was IRQ-6 (Populus nigra).

The measurements were made on the wood of trees planted at spacing of 1x4, 2x4, 3x4 and 4x4 m.. Some selected anatomical properties namely: fiber length, fiber diameter, fiber wall thickness, vessel element length and diameter, and the specific gravity were studied.

The results showed a significant effect of spacing upon all the properties studied, fibers and vessel elements dimensions along with the specific gravity were found to be higher in trees planted at 2x4 m compared to those planted at other spaces, except for vessel elements diameter which was a little lower.

Variations of the properties studied in the radial direction were higher than those along the stem axis. Fiber and vessel elements diameter which showed an increasing values at first and then it decreased near the bark. The means of the specific gravity were found to be higher near the pith compared to the means close to the bark.

Fiber dimensions and vessel elements diameter decreased with respect to height in stem, while no clear trend was found in case of vessel elements length. The mean specific gravity increased with height in stem.

533 UTILIZATION OF WASTE OF KATHA INDUSTRY FOR PAPER AND HARD BOARD PRODUCTION

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Acacia catechu (Khair) is an important industrial tree, as its heartwood is used for the extraction of katha and cutch. Twenty small scale industries and a number of cottage industries are using about one lakh tons of *Khair* annualy. Approximate composition of heartwood is 40-50% of total. The sapwood and the spent heartwood (after extraction) are left as waste and find no use expect partially as fuel. The studies conducted to use this waste material in paper manufacturing, revealed that the steength properties of paper from this pulp fulfil the requirements of writting and printing paper. As paper industry requires a large amount of raw material, so blending of sapwood and spent heartwood pulp with 25% bamboo kraft pulp or Bhabhar grass soda pulp was tried, which resulted in improved quality of paper. The sapwood, exhausted heartwood and the mixture of both, were also used to prepare the hardboard. The board thus formed was found to match the specifications for standard hardboard after heat or oil tempering. The mixture of sapwood and spent heartwood (1:1) was further mixed with the equal amount of *Populus ciliata* wood and the hard board thus obtained ranged among the quality hardboards.

534 A STUDY OF PARAMETERS AFFECTING CHARCOAL STOVE PERFORMANCE

P Khummongkol (School of Energy and Materials, King Mongkut Institute of Technology Thonburi, Bangkok, Thailand)

A charcoal bucket stove - a popular type of biomass cooking stove in Thailand - is selected as a model of this study. The performance of the stove is evaluated in terms of heat utilization efficiency using the water boiling test method. The physical parameters of the stove such as the size of the air inlet area, gas exhausted area, grate to pot distance, grate hole area, and wall thickness have governing effects on the efficiency of the stove. The external parameters which include the size of charcoal fuel and the initial amount of water used in the water boiling test are also important factors that influence the efficiency value of the stove. The quantity of heat loss by convection, conduction and radiation through various parts of the stove have been measured in order to determine their effects on the deduction of the stove efficiency. The flow rates of air into and exhaust gas out of the combustion chamber were experimentally determined.

535 VARIABILITY IN WOOD QUALITY OF JAPANESE LARCH OBSERVED BY TREE BENDING TEST

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In recent days, increasing attempts have been made using lumber in various structures in Japan. Accompanied with this tendency and demand for utilizing domestic plantation grown trees, concerns about grading systems and variability in strength properties of material arise. In this paper, variations in modulus of elasticity (MOE) of Japanese larch (Larix kaempferi) caused by genetic and environmental differences were discussed. The MOEs of tree trunks determined by non-destructive tree bending test were used as a predictor of qualities. The test apparatus consists of a lever arm that converts operator's weight into bending moment and a middle-ordinate gage, which can easily be applied in forest sites. A series of tree bending tests in plantations was conducted with following results. Trunk MOE had considerably smaller variances within plus-tree clones than among clones. Although MOEs had greater variances within offspring families, the broad-sense heritability of strength properties could be expected to be large. The MOEs had highly significant differences among provenances. Average MOEs for stands of suitable environments for growth characteristics were greater than those of adverse sites. Since the relative sample stands, which were established in the same years with seedlings from identical nurseries, located in the same districts, local environmental effects would account for much of the disparity of MOE values. These characteristics of large amounts of genetic variations and strong heritability for trunk MOE, as well as the site effects leading to both higher yields and better quality, recommends Japanese larch as a promising species for lumber use.

536 MOLDING OF STRUCTURAL PAPER PRODUCTS FROM WOOD FIBERS

Theodore L. Laufenberg and John F. Hunt, Research Engineers, U.S. Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53707.

Two unique paper fiber processing methods have been developed to directly form three-dimensional structural products from fibers. The two processes are related material-processing concepts and produce a patented line of products called SPACEBOARD.

Adaptation of traditional fourdrinier paper-making technology, through the press-drying concept, dries the paper fibers under z-direction restraint. By mounting three-dimensional silicone pads to the wire screen the fibers form around the pads and then are pressed and dried on the fourdrinier screen with silicone pads. Results from static trials show that the critical strength properties and stiffness of this new paper product is significantly greater than the same weight of commercially available corrugated paper structure. This paper machine adaptable product promises to revolutionize the paper-based container industry. Use of short hardwood fibers and recycled paper fiber is encouraged due to the enhanced bonding from restrained drying of the structure and all paper fibers are more efficient from greater fiber alignment in the inter-mold spaces.

Fiber-based structural components have until now been limited to planar configurations. This processing breakthrough opens the door to highly efficient structurally-designed components. The restrained drying also provides added wet strength for the paper fiber network. Uses envisioned for the concept will capitalize on the ability to form a product with ribs, plates, or other structure for the improved performance of a specific end-use application.

537 ANALYSIS OF SOME BASIC PARAMETERS OF TURKEY OAK (*Quercus cerris* .) WOOD RELATED TO ITS GLUABILITY

P. LAVISCI*, D. MASSON, X. DEGLISE (ESSTIB - Université de Nancy I, Vandoeuvre France, * Instituto di Assestamento e Tecnologia Forestale - Université de Florence, Italie).

An analysis of some chemical and physical parameters of the wood of Turkey Oak, which have an influence on its bonding properties, was necessary for the interpretation of the results of some previous mechanical tests on the glued joints. The wood pH is perfectly compatible with the commonly used wood adhesives and wood wettability is good and there is no evidence of the presence of important quantities of non-polar extractives. There is no appreciable migration of the wood extractives to the surface and no evidence of their deposition on the pit membranes dimminishing wood's microporosity. Moreover, the wood of Turkey Oak contains very little quantities of polyphenols and practically no ellagitannins. Thus, even if the presence of a factor causing inactivation to gluing cannot be absolutely excluded, it is more probable that the gluing difficulties of this wood are of the same nature as those off other oak species wood with a comparable density (0,8-0,9 g/cm^3 at 12% EMC).

538 ON-LINE FIBER SATURATION POINT DETECTION IN DRYING LUMBER

Lessard,R.A. and Hill,J.H.(Norwich University, Northfield VT and University of New Hampshire, Durham NH)

Electrical conductance sensors are the best available method to monitor the changing moisture content gradient at specific locations in drying lumber. Commercial wood moisture monitoring systems, however, have a high degree of uncertainty in moisture estimation particularly at and above the Fiber Saturation Point (FSP)--the shrinkage threshold; but on-line FSP estimation with conductance electrodes is unaffected by this uncertainty. A method is proposed for estimating the FSP occurrence that uses the technique designed to detect the returning pulse in radar correlation receivers. The on-line conductance sensor time-series is correlated with a model of an ideal pre-FSP time-series. As the on-line conductance time-series grows, the correlation (on-line to model) is calculated producing a corresponding time-series of correlation values. When the correlation time-series peaks at or near 1.0, it means that the pre-FSP on-line conductance series most closely matches the pre-FSP model behavior. A preliminary analysis from existing drying test conductance data indicates a potential accuracy of +/- .5% is possible for a commercial moisture sensing system and that cross correlation detected the FSP event-time or peak in 93 of the 100 sensors tested in 8/4 red oak. This dry run data suggests that the FSP event-time can be determined at the electrode tips for each sensor site with sufficient validity and accuracy to provide improved drying defect control. This paper will report on our first test of the concept on-line in a laboratory scale dry kiln at UNH

539 OAK DECLINE IN NORTHERN GERMANY
- DISTRIBUTION, SYMPTOMS, PROBABLE CAUSES -

Lewark, S., Hartmann, G. and Blank, R. (University of Göttingen/Forest Research Institute of Lower Saxony, Göttingen, FRG)

In stands of *Quercus robur* L. and *Q. petraea* LIEBL. on a wide range of forest sites in Northern Germany declining trees of all ages and social classes have been observed since 1985. Comparative tree ring analyses suggest winterfrost damage to be the primary cause, preceded by predisposing phases of reduced radial increment, caused by droughts.

Main symptoms are sparce foliage due to premature shedding of branches and leaves, die back, bark necrosis and ultimately Armillaria root rot. Two types can be distinguished: (A) trees are killed by necrotic girdeling in the lower or middle parts of the stem; (B) trees die by die back of twigs and branches, expanding from the top downwards into the upper part of the stem.

In type A primary damage by winterfrost shows in form of narrow, vertical stripes of dark brown necrotic bast tissue, which may close by wound healing, producing wound (frost) ribs, or they enlarge to girdle the stem within 1-3 years after primary damage.

Weakly parasitic fungi are constantly associated with progressing secondary necrosis. Ceratocystis species were isolated from older necrotic bark, but rarely from newly formed bark necroses.

Soil acidification due to deposition of air pollutants is being discussed as a possible cause of root damage, predisposing oak to decline.

540 STUDIES ON THE FABRICATION OF END JOINTED LAMINATED WOOD FROM TAIWAN RED PINE, HONDURAS MAHOGANY AND COMMO TEAK.

Cheng-Tzu Liu, National Chung Hsing Univ., Taichung, Taiwan, Republic of China.

The purpose of this study was to investigate the properties of 4-ply laminated wood made from Taiwan Red Pine, Honduras Mahogany and Common Teak with butt, scarf and finger joint by UF adhesive, and with different location of joint in laminated wood. The results obtained were as follows:

1. The strength of butt join laminated wood could be improved when the distance between each butt join increased, when use the full-length lamina as bottom lamina in laminated wood, its strength would be improved significantly and up to the strength of laminated wood made from four full-length laminas.
2. The strength of scarf joint laminated wood could be improved as increasing either the ratio of horizontal length (L) to vertical length (H) of the slope or the distance between each scarf joint. The over all strength could be improved obviously when use the full-length lamina as bottom lamina in scarf joint laminated wood.
3. The bending strength of finger joint laminated wood was slightly lower than the scarf joint laminated wood with L/H ratio of 8.0. The strength of finger joint laminated wood had a little or no progress as the finger joint position in each lamina was not on a line.

541 **Potential markets for composite products from wood and nonwood materials. Marcin, T.C. (USDA Forest Service, Forest Products Laboratory, Madison, WI 53705-2398, U.S.A.)** Composite products are an important and growing segment of the forest products industry. Material science has provided new technological capabilities that can provide increased benefits from composite combinations of wood and nonwood materials. In addition to existing composites such as plywood, laminated veneer products, various fiberboards, wafer-OSB panels, particle boards, overlays, and composite lumber substitutes, a new class of composite products combines wood and nonwood materials in a material matrix. Material combinations include wood-metals, wood-plastics, wood-plastic alloy, and wood-synthetic fibers. Products include those for high-performance applications, such as windmill turbine blades and musical instruments, or basic applications, such as cost-effective building products or automobile components.

The potential for combining wood with nonwood materials permits a manufacturer to consider a wide range of potential new products having performance characteristics that benefit from both materials. For example, wood may provide light weight and low cost; metal, strength and toughness; and plastics, moldability and durability. Wood and other natural fibers are strong, lightweight, abundant, and nonhazardous and are thus excellent additions for many types of plastics.

This poster presentation addresses potential markets for this new class of composite products. Also displayed is an example of moldable fiber mats combining plastics and natural fibers, suitable for molded components of automobiles and pallets.

542 XYLOFOAM: A WOOD-FOAM COMPOSITE

Alan A. Marra, Professor, University of Massachusetts, (Retired)

Xylofoam is a composite of specially comminuted wood particles suffused with foaming binders. The composite is formable into many different kinds of products, with strength related to a density range of 8 to 40 pcf. The particles are derived from low grade or waste green wood of most species. Their special configuration accounts for unique properties both in process and in product, variable densities and variable cross sections, high orientation for maximum strength or complete disorientation for maximum internal integrity. In a typical production operation, the wood particles are formed into a loose mat on a moving belt carrying an overlay or release paper, the foamable binder is applied, a top overlay fed in, and a continuous board press completes the process at low pressure. The binder foams and cures without heat, consolidating the mat and bonding the overlay. Forming to various shapes can be accomplished before the binder totally cures. Alternatively, the mat can be transferred to or formed in a mold for direct shape generation. The simplicity, low cost, and versatility of the process allow scale up or scale down to reconcile markets, material resources, financial resources, and human resources over a wide range.

543 CARDIN: A COMPUTER SYSTEM FOR THE SIMULATION OF FOREST FIRE SPREAD

Martinez-Millan, J. and Caballero, D. (Escuela Tecnica Superior de Ingenieros de Montes, 28040 Madrid, Espana).

CARDIN is a computer user-driven forest fire behavior simulation system based on digital geographic data, namely fuel distribution and topographical coverages, working on a PC computer. Other inputs belongs to general wind properties (intensity and direction), and fuel status (moisture and wind protection degree). It is allowed to modify the parameters at any time user requests as the simulation progress. There is no limit about the number, size and shape of the initial focus points, and new ones can be added at any time within the simulation. CARDIN digital coverages are provided by its own digitizing system, DIGICAR.

The calculus and fire spread fundamentals are the same as used in BEHAVE system.

Periodic reports about the perimeters, areas and shapes of burned surfaces, are provided automatically at pre-set intervals of time. Graphics representations are given to evaluate the geographic situation and fire shape over 2D coverages, and visual impact of burned areas on a more realistic 3D images.

This project has been supported by the ''Servicio de Defensa Contra Incendios Forestales'', Instituto Nacional para la Conservacion de la Naturaleza, Madrid, Espana.

544 LAYOUT OF A SMALL SOLAR TIMBER DRYER FOR HUMID TROPICAL REGIONS *

Matos, J.M. and Vetter, R.E. (Instituto Nacional de Pesquisas da Amazônia, Manaus, Brazil)

Furniture works with two to five employees usually do not process more than 5 m^3 sawn wood from different species per month. Commercially available kilns are expensive and difficult to operate; often they do not resist the humid tropical climate. These observations implied the development of an economic, easy to construct and simple to operate solar timber dryer. Air ducts connect the humidity sealed drying chamber (4x4x2,5 m) with the 20 m^2 flat, greenhouselike roof. Two fans provide a 2-3 m/s air circulation in the timber piles. Narrow damper openings allow to dry a species mixture carefully from 70% to 10% moisture content in 30 days. Efficiency is about 25%. For less than US$ 5000 the dryer can be constructed in 1-2 weeks.

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* Project Financed by IDRC, Ottawa, Canada

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MANUFACTURING AND TESTING PLYWOOD FROM WHITE QUEBRACHO AND COTTONWOOD [1]

Juan Carlos Medina
Profesor Adjunto
y
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Santiago del Estero, Argentina

The results of the evaluation of some physical and mechanical properties of plywood from *Aspidosperma quebracho-blanco* Schlecht. (QB) and *Populus* sp. (A) are presented in this paper. The panels were built using a mixture of veneers of both species in different proportions and positions. The values obtained from the mechanical tests were analyzed in order to identify the best panels. Experimental MOR values were compared with those published for structural pine plywood of the CDX type, taking into account the corresponding specific gravity values of each panel. As expected, the statistical analyses showed that no single panel is the best for all tests. However, based on the comparison of MOR values, it was concluded that the best panel was the one containing 30 percent QB and 70 percent A, with the structural arrangement QB QB A A A A A A A QB QB. In addition, three of the test panels exhibited MOR values (both parallel and perpendicular) that were higher than those published for the pine plywood. Further research using various arrangements for the same percent composition is recommended to gain a better understanding of the effect of structure on the mechanical properties of this type of plywood.

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THE INFLUENCE OF MINERAL FERTILIZATIONS ON WOOD STRUCTURE OF THE PINE Pinus silvestris

Melekhov, I.S., Stepanenko, I.I. Department of Forestry, Moscow Forestry - Technical Institute Mytishi - 1, Moscow rigeon, 141001, Moscow, USSR

The correlation between forest fertilization and wood structure was shown. The features of ultrastructure of wood components (early and late wood, growth ring, tracheids) in different trials were compared.

547 FLORISTIC STUDY OF RATTANS IN SULAWESI -- INDONESIA*

MOGEA, J.P. (Herbarium Bogoriense, Centre for Research and Development
in Biology -- L.I.P.I., Bogor, Indonesia).

The land area of Indonesia is *ca* 2,000,000 sq kms, about 60% of the land area is covered by forest. The forest contribute about 90% of world rattan market. Sulawesi is a third biggest wild rattan production centre following after Kalimantan and Sumatra. The rattans in Sulawesi consist of 21 known species of *Calamus*, 5 known species of *Daemonorops* and *Korthalsia celebica*. Recent field work revealed that there are may be *ca* 10 undescribed taxa can be found under *Calamu* and *Daemonorops*. A key of identification to the species, significant characters, geographical distribution, ecology, conservation status, quality of cane and others botanical informations are discussed. About 8 species of canes are commonly on sale in local as well as internatio trades, such as canes of *batang* group of 30 -- 50 mm in diameter (consists of 4 species, among them is *D. robusta*); *tohiti and ombol* gr of 15 mm in diameter (consists of 7 species, among them is *C. inops*); and *jarmasi or ronti* group of 5 mm in diameter (consists of 6 species, among them is *C. minahassae*).

*A grant from the International Development Research Centre,
Ottawa, Canada.

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548 MARKETING (OR TECHNOLOGY TRANSFER) OF FOREST PRODUCTS AND FOREST PRODUCTS MARKETING RESEARCH -- THE EXPERIENCE AND THE POTENTIAL OF EXTENSION (ADVISORY) SERVICES. Dr. Donald E. Nelson, (National Program Leader -- Wood Products Marketing United States Department of Agriculture - Extension Service, Natural Resources and Rural Development Unit, 3871-South Building, Washington, DC 20250) Is *marketing* of *research* a legitimate topic for forest products marketing researchers? Do those who do marketing research, because they have a specialized knowledge of marketing, make a special effort to see that their own research is marketed? One might suppose that those who attempt to market research (to transfer technology) would benefit from market research that uncovers the most effective methods. This poster discusses methods for improving the marketing of research results.

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INVESTIGATION OF THE EFFECT OF ANNUAL GROWTH RING WIDTH ON WOOD QUALITY

Asghar Omidwar Dean: College of Natural Resources
University of Agricultural and Natural Resources Sciences

The summary of results obtained are as follow:

1)- The results of anatomical tests have shown that wood with smaller growth rings have the biggest amount of resin canals and alsoprosity. Thus the higher amount of wood material per unit valume and also the density is expected, which is considered a favorable growth condition for pulp and paper industries. Hence,for producing high quality raw material a close cooperation between forestry and these industries is inevitable.

2)-Physical and mechanical properties tests showed that trees with smaller annual growth ring have higher compression and bending strenght, thus are more suitable for construction purposes.

3)-Because of lower tangential shrinkage than radial shirinkage and also lower amount of wood texture in wider growth ring, increasing the distance between trees in a proper sylvicultural practices and increasing harvesting time of this specis, the large logs can be utilized for veneer, playwood and carpentery purposes.

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TREND AND PROSPECTS OF THE PULP AND PAPER INDUSTRY IN INDONESIA

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Research Scientist
Forest Products Research and Development Centre, Bogor, Indonesia

Integrated pulp and paper industry, paper industry, and pulp industry appear to grow fast either in number of industries, in their production or in the kinds of papers to be produced. Unfortunately those three kinds of pulp and paper industries still reveal lacks in structural and operational field.

The details of Indonesian consumption for paper products in 1988 are as follows : industrial papers reach the first rank and than followed by culture paper (newsprint, and wisting/printing paper), and others of low quality paper. Aproximately, the consumption pattern of that consumption will be more or less the same by the year of 2000. However, the fast trends of paper consumption in Indonesia can not be coped with by the production from the existing pulp and paper industries using the present skills,equipments, and technologies.

As an effort to overcome that problem, the Indonesian government has released some priority programs as follows : establishing of erecting pulp and paper industries with their considerably large designed capacity ; and planting industrial forest (timber estate) from which the wood can be extracted as raw material for pulp and paper.

Eventually, to support those Indonesian government programs, first of all research and development activities are worth carrying out either in knowledge or in applied technologies which are necessary for the field or aspects of pulp and paper.

551 THE LATEST DEVELOPMENTS IN CHARCOAL TRANSPORATION IN BRAZIL

Rozov, V, Sulzbacher, G (R&D Engineering Department S/A Agro Industrial Eldorado Sao Paulo, Brazil)

Almost the whole Brazilian charcoal production of approximately 9 million tons per year, is transported by trucks for distances that vary from a few hundred to over one thousand kilometres. There are two traditional ways to do this: Using a bag of around 25 kg capacity, or trucks equipped with special wooden loading compartments, up to three metres high, known as "CAGE". A third method of transportation was introduced successfully a few years ago. It uses a rigid, low weight container of all steel or mixed wood steel construction. Having 2 tons capacity the container has intermodal transportation capability, is size compatible with standard 20 foot ISO container, has excellent road stability and is either collapsed or disassembled for return trips. A very large reduction of pollution by charcoal dust was achieved during transportation and unloading operations. Container solid walls protect charcoal from humidity and mechanical damage. Such dry and low fines content charcoal commands premium price. All three methods are compared. The advantages and drawbacks of each are discussed. The transportation of charcoal by container has proved to be cheaper, more productive, mainly on loading and unloading operations, less polluting, intermodally efficient and forest preservation oriented, by lowering losses through degradation during transportation.

552 HEARTWOOD FORMATION IN *PINUS SYLVESTRIS* L.

Saranpää, P. (Department of Logging and Utilization of Forest Products, University of Helsinki, Finland)

Cytological and biochemical changes related to heartwood formation were studied in large Scots pine stems. The plastids in the xylem ray parenchyma cells were found to resemble amyloplasts and displayed large variation in the structure and starch content, particularly in the sapwood-heartwood transition zone. In the sapwood the amounts of fatty acids of triacylglycerols were about 1.5 % (dry weight) but a large reduction occurred in the transition zone. In contrast, noticeable amounts of free fatty acids were found only in the heartwood. The amount of sterols was also greatest in the heartwood. The amounts of glucose, fructose, sucrose and raffinose/stachyose were greatest in the outer sapwood and decreased gradually towards the heartwood. In contrast, the level of arabinose/galactose increased towards the heartwood and the largest amount was found in the inner heartwood. The amount of starch decreased markedly towards the heartwood. However, variation between the stems studied was fairly large.

553 THE POSSIBILITY OF SUBSTITUTING LOCAL LOBLOLLY PINE KRAFT PULP WITH THE IMPORTED LONG-FIBER PULP IN ADMIXTURE WITH LOCAL MIXED HARDWOOD PULPS.

A. R. Saryian, University of Agriculture and Natural Resources Science, Gorgan, Iran

The possibility of substituting local loblolly pine kraft pulp with the imported long-fiber pulp in admixture with local mixed hardwood pulps, was investigated. Chemical compositions of the loblolly pine wood, of different classes of diameter was determined. The average quantities for cellulose, lignin, extractives, and ash contents was 48.76, 27.3, 3.1, and 0.49 percent respectively.

Kraft pulp was prepared under the following cooking conditions:

Active alkali = 20% (as Na_2O)
Sulfidity = 25%
Liquor to wood ratio = 4:1
Maximum cooking temp. = 170°
Pressure = 90 PSI
Cooking time at maximum temp. = 125 min

The yield and kappa number of this pulp was 43% and 34, respectively. The pulps of loblolly pine wood and imported long fibers with equal kappa number was refined to equal freeness of 650 ml, osf.

Handsheets were made from pure pulps of each of the loblolly pine wood, imported long-fiber, local mixed hardwood pulps as well as admixtures of local mixed hardwood pulps with 10, 15, and 20 percent of each of the two softwood pulps. The strength properties of these different types of handsheets was determined and the results was analyzed using complete randomized design method.

The results of this investigation indicates that comparable strength properties can be produced when local loblolly pine kraft pulp is substitute with the imported long-fiber pulp in different admixtures with local mixed hardwood pulps.

554 PROPERTIES OF NEW WHITE WILLOW CLONES SUITABLE FOR PULP PRODUCTION

Sertić, V., (Faculty of Forestry, Zagreb), Melcer, I. and Melcer, A. (University of Forestry and Wood Technology, Zvolen).

Mechanical and chemical properties of the pulp obtained from two new white wilow clones have been investigated. The eximaned samples have been selected as the best examples exhibiting very high phenotype stability and very good productivity. The are also resistant to the flood and suitable for the growing of multiclone culture at the site of plane forest which are unsuitable for growing of valuable kinds of woods. Mechanical and chemical properties of the samples of the juvenile wood of the five new white wilow clones have been also investigated. The investigations have been of the pilot character to provide the results which might be used as indicators of genetic origin. Two yeary old seeds of the white willows have been used in the investigations.

555 WOOD QUALITY OF JAPANESE LARCH IN RELATION TO ITS GROWTH

Shigematsu, Y.
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Japanese larch (Larix leptolepis Gordon) has been planted for about 100 years particularly in the central part of Japan, the Chubu-Mountain district. Using old planted Japanese larch, the variations of some wood quality factors such as the tracheid length and specific gravity were investigated putting in consideration on the effect of the rate of growth.

The variations of tracheid length in stem were clarified along the radial and longitudinal directions. The patterns of the tracheid length change within one year growth were obtained at five different numbers of annual rings along the radial direction.

The variations of the specific gravity in stem at air-dry condition were obtained. Also, the density variations of early and late wood in radial direction were observed with the X-ray Densitometry.

An apparent negative relationship was obtained between specific gravity and annual ring width, and a positive relationship was observed between specific gravity and late wood ratio.

It was revealed that the annual ring structures (quality and quantity of early and late wood) varied according to the growth of the tree. This structure was affected by the planting density and thinning.

556 SILYLATION AND PHOSPHORYLATION OF WOOD

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Processes of silylation and phosphorylation of wood accompanied by modification of wood and its components, with formation of chemical bonds $Cell{-}O{-}P\equiv$, $Cell{-}O{-}Si<$ result in increasing of wood durability and its product. The study of these processes allows to work out modification conditions at 20°C. Element content of phosphor is 0.7 - 0.84%.When silylation pre-phosphorylated wood it is possible to get 0.4 - 0.6 % of silicon in samples at 20°C.

We suppose that while silylation and phosphorylation wood and cellulose there takes place certain coordination of silicon-organic compounds with formation of an intermediate which includes coordination like $Cell{-}P{=}O{-}Si\equiv^{OR}\cdots Cell$ an so interrelation.While modyfication of wood we succeded in forming the wood into fire retardant materials. While silylation of phosphorylated wood under elaborated conditions the wood permeability decreases in 2.5 times, and the wood becomes a bioligical and fireresistant material.

557 DETERMINATION AND USE OF MOISTURE DIFFUSION AND SURFACE EMISSION COEFFICIENTS OF WOOD

Simpson, William T. and Liu, J. Y. (Forest Products Laboratory, Madison, WI, USA

The dependence of the diffusion coefficient of water in aspen (Populus sp.) on moisture content between 0 and 18 percent at 43 C was determined by an experimental method that requires a series of absorption experiments and application of a numerical method for solving the diffusion equation with a moisture content dependent diffusion coefficient. The diffusion coefficient was found to increase exponentially with moisture content. The numerical method also includes variable boundary conditions, as defined by the surface emission coefficient, so that the effect of surface equilibrium moisture content can be examined. The experimental moisture content-time curves can be generated by the numerical methods with an average deviation of 0.2 percent moisture content and a worst-case deviation of 0.7 percent moisture content. Practical implications and uses of the analysis, such as for analyzing 1) moisture content gradients and the effect of the surface emission coefficient on them; 2) the effect of the surface emission coefficient on sorption rate; and 3) the effect of errors in boundary conditions on the predictive ability of the numerical methods, are also discussed.

558 New Product Development: How Do We Evaluate the New Product's Potential?

Steven A. Sinclair and Mark W. Trinka (Department of Wood Science and Forest Products, Virginia Polytechnic Institute and State University, Blacksburg, VA 24016-0503, USA). New products have been called essential to business success. They provide new opportunities for business growth, enhanced profits and increased employment. Much has been written on the process of encouraging a business to be new product oriented with "product champions" and so forth. Other studies have explored the statistics of how many new product ideas must be surfaced to get one new successful product. Much less study has been devoted to developing a methodology to evaluate the potential of a new product in the market.

This effort purposes the use of a modified 20 cell product/market attractiveness matrix as a tool to measure market potential for a new product. The x-axis has four categories corresponding to the four stages of the product life cycle; introduction, growth, maturity and decline. The y-axis represents a quantitative measure of the new product's performance as compared to substitute products in the marketplace. The new product is rated on the y-axis as strongly superior, somewhat superior, equal, somewhat inferior, or strongly inferior to existing substitute products. This performance ranking is accomplished by a survey of potential buyers.

New products superior to existing products in the introduction or growth stages of the market are posited to be more likely to be successful. And, new products which rank inferior to existing products and fall in the mature or declining stage are posited to be more likely to fail.

559 EFFICIENT USE OF SUGAR PALM LEAFSTALKS FOR ENERGY PRODUCTION*

Prapasri Singrat (M. App. Sci. (Food Eng.), Department of Agro-Industry, Faculty of Natural Resources, Prince of Songkla University, Hat Yai Campus, Thailand)

The palm sugar production in Sathing Phra Peninsula depends heavily on the para rubber wood for the energy required in the process. This wood as fuel, is highly demanded by other industries and has become a major cash cost in sugar production. This is due to the government's policy on the wood cutting concession. Sugar palm leafstalk which is readily available in the area, is economically very attractive as a source of heat energy that can replace para rubber wood. In order to use sugar palm leafstalk as a source of energy, the fuel properties of sugar palm leafstalk were studied. The proximate as well as ultimate chemical analyses and the calorific value of sugar palm leafstalk were presented. Based on these analyses, the constituents of the products of complete combustion and the theoretical air requirements for perfect combustion were also illustrated.

* A contribution to the Thai-French Farming Systems Research Project, Faculty of Natural Resources, Prince of Songkla University, Hat Yai Campus, Thailand

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560 **Analysis of United States softwood lumber and composite panel demands. Spelter, H. (USDA Forest Service, Forest Products Laboratory, Madison, WI 53705–2398, U.S.A.), Haynes, R. (USDA Forest Service, Pacific Northwest Range and Forest Experiment Station, Portland, OR 97208, U.S.A.), & Adams, D. (University of Washington, Seattle, WA 98105, U.S.A.)** Demands for softwood lumber and structural composite panels in the United States were disaggregated and analyzed by major end-use markets—chiefly residential and nonresidential construction, manufacturing, and shipping. Trends in wood use were analyzed in terms of economic substitution between competing wood and nonwood products. The effects of price on substitution were modeled using a product diffusion approach, in which the effects of price (price elasticity) vary over the stages of a product's lifecycle (introduction, growth, maturity).

For softwood lumber, price elasticity of demand was inelastic over the postwar era and has tended toward even more inelasticity with time. This indicates the maturation of product substitution cycles and the lack of significant new technologies in the lumber market. Thus, pricing has become a less critical factor in determining final demand for softwood lumber. For softwood plywood, price effects were similarly inelastic; however, elasticity decreased only through the first 30 years of the postwar era and has increased over the past decade. This reflects the technological development of nonveneered structural composites, which have emerged as plywood substitutes in many markets.

In projections to the year 2040, lumber demand is primarily determined by general economic growth whereas demand for plywood and nonveneered structural panels is significantly influenced by price.

561 A COMPARISON OF TOOL MATERIALS, COATINGS, AND TREATMENTS AFTER MACHING MDF.

Stewart, H. A. (Mississippi Forest Products Laboratory, Mississippi State, Mississippi, USA).

Tool wear from machining dry wood and reconstituted wood products such as medium-density fiberboard is caused by high-temperature corrosion/oxidation as well as other wear mechanisms. Refractory tool materials should therefore enhance tool life. Tool materials, coatings, and treatments were compared with a turning method for monitoring tool wear. Previous results showed final tool forces after a predetermined length of cut was a good tool wear index. Turning tests were conducted with 15 degree rake and 10 degree clearance angles and 0.005-inch cross-feed. The results indicate that tool materials, coatings, and treatments which are more refractory have lower tool forces at the end of the tests. Consequently, tool edges of more refractory materials can enhance tool life.

562 "CONDITIONS AND PROSPECTS OF MATERIAL INVESTIGATION IN THE RANGE OF WOOD MATERIAL IN POLAND", by Strykowski, W. and Ratajcak, E.

(Institute of Wood Technology, Winiarska 1, Poznan, Poland

The characteristics of production of main products of industry of wood processing in Poland. The factors creating supply and demand for wood processing products. Amount of exports and imports of main products of wood processing industry with reference to trends. Preferences and limitations. Possibilities of development of new products of wood processing in Poland on the pattern of actual technological gap, state of resources and situation of the employment. Investment possibilities in wood processing sector in Poland for international capital.

563 Acid Catalyzed Delignification of Black Poplar Wood in Aqueous Ethanol

Younis H. Suleman
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Hammam Al-Alil, Mosul, IRAQ

Black poplar (*Populus nigra* L.) wood chips were subjected to aqueous ethanol delignification, the effect of reaction conditions on the degree of delignification was evaluted. Solution of aqeous ethanol of 50% was tested at liquor/wood ratio of 10/1 for up to four hours at 150-170°C in the presence of $AlCl_3$ as a catalyst.

The highest degree of delignification was achieved (residual lignin in treated wood), 8.3% at a temperature of 170°C for reaction time of four hours. The delignification of poplar wood was enhanced by using of $AlCl_3$ at 170°C for 1-4 hours (5.7-7.6% of residual lignin left after treatment).

564 POLYMER REINFORCED FIBER COMPOSITES FOR EXTERIOR APPLICATIONS

Sun, B.C. and Hawke,R.N. (Associate Professor and Graduate Student, School of Forestry and Wood Products, Michigan Technological University, Houghton, Michigan, 49931 USA)

A polymer intermediate was used to form fiber composites for exterior and high strength applications. Thermomechanically pulped aspen fibers were consolidated into 18" X 16" X 0.125" composite panels (1.0 target specific gravity). Similar Panels were also consolidated with phenol-formaldehyde binder for comparison. It was established that (1) panel densities and properties varied with panel composition and consolidation condition, (2) modulus of rupture, internal bond strength, ultimate tensile strength and elasticity parallel to panel face, as high as 17,500, 1,500, 11,500, and 2,200,000 psi, were obtained, respectively, (3) composites retained 80 to 95% of their dry strengths after six-cycles of accelerated aging treatment, (4) accelerated aging treatment caused negative linear expansion, and as low as 3% thickness swelling, and (5) all fiber-polymer composite properties were substantially better than those bonded with phenol-formaldehyde binder.

565 INVESTIGATION ON THE EFFECTS OF MAT MOISTURE CONTENT AND PRESS TIME AND TEMPERATURE ON PARTICLEBOARD QUALITY PRODUCED BY BEECH

Taghi Tabarsa
Faculty Member
University of Agriculture and Natural Resources
Sciences

In this study the effects of three factors : mat moisture content, press temperature and time on properties of particleboard manufactured by beech (Fagus orientalis) were measured.

Randomized blocks as factorial design were used in this study. Urea-formaldehyde was used as adhesive.Above mentioned factors were used as following manner for manufacturing:

- Mat moisture content : 10-13 and 16 percent
- Press Temperature : 150-170 and 190 C°
- Press time : 4-6 and 8 minute

The other factors were equal for all boards. After preparing boards, physical and mechanical properties were measured according to A.S.T.M. Standards and then the data were analysed statistically. Moisture content of mat and press time were important factors on the quality of particleboards and the best result was obtained on 13 percent moisture content, 170 C°and 6 minutes press.

566 ELECTRICAL RESISTANCE OF LIVING TISSUES IN HEALTHY AND DISEASED SILVER FIRS (ABIES ALBA MILL.)

N. Torelli*, K. Cufar*, D. Robic** (* Department of Wood Science and Technology, **Department of Forestry, Biotechnical Faculty Ljubljana, Yugoslavia).

In healthy and variously affected silver firs in the representative silver fir/beech forest association in Slovenian Karst (NW Yugoslavia) the "horizontal" and the "vertical" electrical resistance (ER) were determined. General and seasonal influences on ER readings were discussed. In healthy trees the "horizontal" ER at breast height ranged between 6-9 kΩ and in heavily diseased between 15-22 kΩ. The "vertical" ER measurements (depth of electrode penetration 7 mm) were accomplished at four locations: (1) periphery of nonconducting phloem, (2) central part of nonconducting phloem, (3) innermost part of nonconducting phloem and (4) cambial zone. In healthy trees the ER at location (1) ranged 10-18, at (2) 10-13, at (3) 9-12, at (4) 9-12 kΩ and in heavily diseased trees at the same locations (1) 15-30, (2) 14-16, (3) 11-24 and (4) 10-22 kΩ.

567 SPRUCE CUTTING ANALYSIS WITH GROWTH CONDITIONS

P. TRIBOULOT(1), J.-M. LEBAN(2), P. MARTIN(1)

French softwoods (fir, spruce, northern pine, ...) have annual rings larger than northern softwoods. Yet it has been shown that an objective analysis conclued to equivalent values of the mechanical and physical properties for the two kinds of origin.

So we have studied the cutting performance in relation with the growth condition. Two batchs of spruce with different anatomical and physical properties have been chosen :

batch a = mean specific gravity 340 kg/m^3 annual ring 7 mm

batch b = mean specific gravity 420 kg/m^3 annual ring 3 mm

The boards have been planed with industrial cutting conditions : cutting speed : 38 m/s, feed 10 m/mn and the cutting forces have been measured.

Also, these parameters are measured on the product :

- chip formation
- dimension scattering
- surface roughness.

This surface roughness is determine with different criteria and not only by the maximum value of pick hight. So with these different parameters it is possible to obtain a good and objective evaluation of the quality and cutting performances.

The large annual rings spruces have the same cutting performances than the narrow rings spruces and give better surface quality. An explanation of the relation between surface roughness and physicals properties is given.

(1) ESSTIB - Epinal, France ; (2) INRA-CRF - Champenoux, France

568 DSC AND FTIR STUDY ON THE POLYMERIZATION AND THE HYDROLYSIS OF UREA FORMALDEHYDE ADHESIVE

C.T. TSOU, D. MASSON, X. DEGLISE (ESSTIB - Université de Nancy I, Vandoeuvre, France).

Even the role of UF glues in the world wood industry is important, however, up to now, very limited studies were carried out concerning the kinetics of the polymerization of UF glues and their hydrolysis after curing. With the purpose of improving understanding for the further adoption in the wood industry of UF glues, in the study, we have made a detail investigation, with a Differential Scanning Calorimeter (DSC) of PERKIN ELMER DCS 7 type, on the mechanism application, containing different quantity of hardening agents. The curing reactions of UF glues catalyzed were examined. The DSC thermogram showed an exothermic peak and an endothermic peak. The activation energies of the filled and unfilled flour of UF resin were calculated from the data of DSC thermograms according to the mathematics proposed by Arrhenius or Kissinger equation. The evolution of functional grouping of films (40-60 µm) of UF resin after hydrolytic aging was investigated with a Fourier Transform Infrared Spectrophotometer of PERKIN ELMER FTIR 1750 type and DSC. Results of a preliminary study of hydrolyzed UF films by FTIR and DSC show that these techniques provide valuable information and insight into the earliest manifestation of hydrolyzed UF films.

569 A STUDY ON THE CARBONIZATION PROCESS OF WOOD

Yu WEI
(Fujian Forestry College Nanping)

The mechanism of pyrolysis of eight wood-base materials was investigated with a small-scale pyrolyser and LCT differential analytic balance. The changes of the functional groups in charred substances resulted from various temperatures were analysed by means of infrared spectrum. It was found from the results obtained in this study, that water and air in wood escaped and wood components with low molecular weight discomposed first and then the three main components started to degrade almost simultaneously at about 200°C. Reactions of hemicellulose and cellulose were strong, but that of lignin was moderate. The carbonous residues obtained at 400 °C did not form a carbon-graphite structure. But it is estimated according to activation energy that crystalline structure of hexacarbocycle carbon-graphite should be formed at about 600 °C.

Keywords: Destructive distillation of wood; Thermogravimetric analysis; Differential thermal analysis; Carbonous residue

570 HIGH YIELDS OF WOODY BIOMASS FEEDSTOCKS FROM INTENSIVE CULTURE OF SALIX PLANTATIONS

Edwin H White, Professor, Lawrence P Abrahamson, Senior Research Associate, Christoper A Nowak, Instructional Support Specialist, Richard F Kopp, Instructional Support Specialist (College of Environmental Science and Forestry, State University of New York, Syracuse, New York 13210

Intensive culture research with Salix clones and species in eastern North America over the past several years sponsored by NYSERDA, GRI ad NYGG has demonstrated woody biomass feedstock yields of willows up to 15 times greater than native forests. These high yields are a result of techniques designed to develop willow clones for high biomass yields, responsiveness to cultural inputs and high convertibility to methane. Results of the largest willow field plantings in North America demonstrate annual coppice yields of 22 oven-dry tons per hectare. Cultural inputs of fertilization (N, P and K) and irrigation combined to provide these biomass yields.

Use of these willow trees as a renewable feedstock for methane production has another critical benefit in addition to the direct energy value. Growing and converting trees to methane converts carbon directly from the earth's atmosphere and the amount of CO_2 produced by utilizing the methane merely equals the amount stored in the trees while they grow. There is no net addition to the greenhouse gases and while the trees are growing there is a net reduction in CO_2 in the air. In addition, woody biomass can replace fossil fuels and in fact reduce CO_2 in the air; less fossil fuels will be burned.

571 AN ASSESSMENT OF KEY FACTORS AFFECTING THE UTILIZATION OF SHORT LENGTH LUMBER BY THE LUMBER AND FURNITURE INDUSTRIES

Wiedenbeck, J., Araman, P., and Youngs, R. Virginia Polytechnic Institute and State University.

Many hardwood lumber producers in the eastern United States do not produce and sell any lumber shorter than 6 feet in length. The furniture and cabinet industry, the major consumer of the higher grades of hardwood lumber in the U.S., demands 8 foot and longer lumber because the longer lumber is easier to handle given existing system hardware, it yields more of the longest length furniture parts, and the volume per board is higher expediting certain processing operations. Increased utilization of short length lumber would not only improve sawmill recovery, but also would reduce harvesting pressure on the remaining volume of high quality hardwood timber. This study was designed to determine: (1) what volume of short length lumber could be readily produced by sawmills if short length lumber were in greater demand, (2) what the furniture part yield of short length lumber for various cutting bills could be expected to be (in both cross-cut first and rip- first rough mills), and (3) the effect of processing short length lumber in a furniture rough mill on production flow. Sensitivity analyses performed on this data with qualifying assumptions will be valuable in predicting a price for short length lumber that is acceptable to both lumber producers and users.

572 NEW BAMBOO PRODUCTS

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Large, mature culms of bamboo (Phyllostachys pubescens) are cut into sections of desired length and splitted into wide strips. The strips are shaved smoothly on either surface and then treated successively in boiling water and preservatives. After oven drying they are glued together and pressed into different boards under a hot pressing machine. The boards are again either cross or longitudinally cut into blocks of different size which after polished are ready to be used for designing various mosaic patterns for flooring, walling, ceiling and furniture surfacing. Our major products are bamboo wall boards, bamboo mosaic floor boards, bamboo furniture surface plates, bamboo bars and bamboo table ware.

573 THE EFFECT OF HIGH TEMPERATURE DRYING ON THE ANTI-SPLITTING PROPERTIES OF BAMBOO CULM.

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The anatomical structure of bamboo culm is governed by the vascular bundles, their shape, size, arrangement and number. The vascular bundles at the peripheral zone of the culm are small and numerous and at the inner part are large and fewer. There is also no radial cell elements existed on the culm. Due to these peculiar structures, bamboo culms are very easy to split during seasoning.

This problem has been overcome by applying high temperature drying method. When bamboo culm (*Phyllostachys makinoi* Hay.) were dried under elevated temperatures (from 60°C up to 120°C), there were no splits occurred on the culm. This phenomenon is explained based on those findings from chemical composition analysis, mechanical properties associated to their physical changes and Scanning Electron Microscope and X-ray Diffractometer observations.

574 SYNTHESIS OF GUANIDINE CONDENSED PHOSPHATES AND ITS USE IN PAPER

Lao Jie yu and Li Bin (Department of chemistry, Northeast Forestry University, Harbin, china)

Paper and its products are one of cellulosic materials. They often give rise to fire because of their flammiblity. In the past, ammonium phosphate sulfate. silfamate, boric acid and borax were used as flamere tardants for paper. paper strength and thermal stability decreased. Since 1960 it was found that guanidine salts are used as flame retardants for paper. T hey possess good fleme retardancy and compatibility. At presant, with dicyandimide, ammonium dihydrogen phosphate and urea as raw materials, a water-soluble guanidine salt flame retardant is prepared by fusing reaction of them in a sealed vessel. Its main component is guanidine condensed phosphates. Guanidine content is 27% by weight in the product. Filter paper is treated wth this flame retardant(FR) or water-soluble ammonium polyphosphate (APP). Flame retardncy of the FR is better than that of water-soluble APP by oxgen Index and 45° combustion test. Thermal stability of the filter paper treated with the FR is good. Immersion insulating paper is impregnated with the FR. when add-on of the FR is 11. 3%, OI is 30.5. char length 6.5cm. All of properties of immersion insulating paper are measured. They reach G · B standard. The paper treated shows good hand.

575 EFFECT OF GROWTH RATE ON WOOD SPECIFIC GRAVITY OF EAST-LIAONING OAK (Q. LIAOTUNGENSIS KOIDZ.)

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Five dominant East-Liaoning Oaks (Q. liaotungensis Koidz.) were collected from Mount Zhongtiao, North China. Effect of growth rate on wood specific gravity was studied, and statistically compared with the effect of age (number of rings from the pith). Results revealed that age is a decisive factor controlling wood specific gravity, while the effect of growth rate is less important. Furthermore, it was found that effect of growth rate varies with ring width range, age and position within a ring (earlywood, latewood or the entire ring). In narrow rings (up to about 1.5 mm), specific gravity increases rapidly with increasing ring width; in rings of 1.5-about 3.0 mm it increases more slowly, and beyond 3.0 mm it remains constant or even decreases. Growth rate shows little effect on specific gravity of juvenile wood, but with increasing age the effect gradually increases to reach a significant level in mature wood. Growth rate does not affect specific gravity of latewood significantly, but shows a considerable effect on specific gravity of the entire ring due to changing early/latewood ratios.

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576 BAMBOO SECTION BOARDS

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Bamboo section boards are made of the blocks of cross-sectioned culms which are treated with preservatives and fastened together with glue under a hot pressing machine. The blocks are arranged to form different mosaic patterns and show their natural colour and beautiful grains on the surface. They are durable pollutionless and poisonless as compared with plastic products and are ideal material for flooring, walling and furniture surfacing. Their physical and mechanical properties are featured with 0.74-0.78 g;cm^2 in volume weight, 10-14% in moisture content, 0.027%, 0.140% and 0.072% in longitudinal, cross and radial shrinkages respectively. Their thermal conductivity is 0.1802 w;m.°C and electric resistance is 32.11 x 10^6 Ohm.M.